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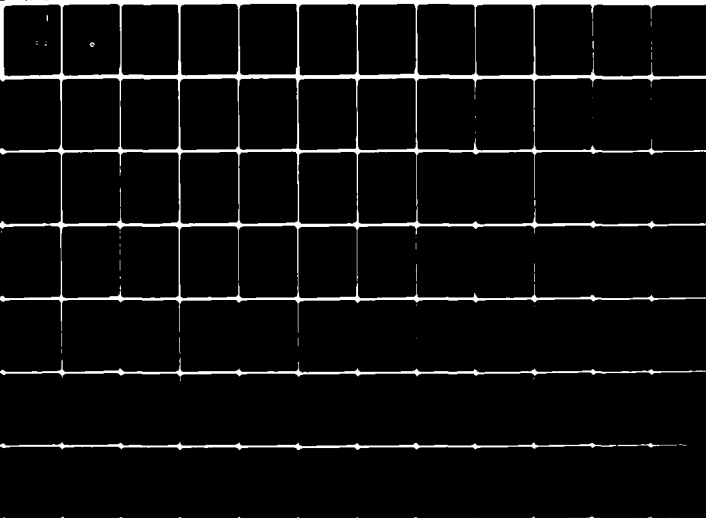
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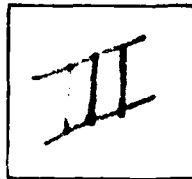
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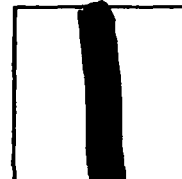
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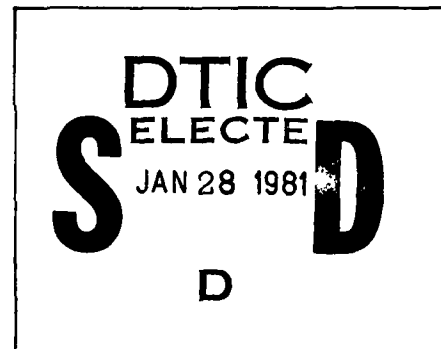
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# **HIGH VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION**

## **TASK 2 SUPPLEMENT - COMPUTER PROGRAM FOR CALCULATING THE AEROACOUSTIC CHARACTERISTICS OF JETS FROM NOZZLES OF ARBITRARY SHAPE**

TECHNICAL CONTRIBUTOR:

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AIRCRAFT ENGINE GROUP  
CINCINNATI, OHIO 45215**



**MAY 1978**

**FINAL REPORT**

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**Prepared for**

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FEDERAL AVIATION ADMINISTRATION  
Systems Research & Development Service  
Washington, D.C. 20590**

AD A094292

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15. Supplementary Notes This report is in partial fulfillment of the subject program. Related documents to be issued in the course of the program include final reports of the following tasks: Task 1 - Activation of Facilities and Validation of Source Location Techniques; Task 1 Supplement - Certification of the General Electric Jet Noise Anechoic Test Facility; Task 2 - Theoretical Developments and Basic Experiments; Task 3 - Experimental Investigation of Suppression Principles; Task 4 - Development/Evaluation of Techniques for "Inflight" Investigation; Task 5 - Investigation of "Inflight" Aeroacoustic Effects; Task 6 - Noise Abate Nozzle Design Guide.					
16. Abstract  A computational procedure is presented for predicting the aerodynamic and acoustic characteristics of jets from nozzles of arbitrary shape. The procedure treats the jet plume as a collection of uncorrelated multipole sound sources which convect with the flow. The aerodynamic characteristics of the jet are evaluated utilizing an extension of Reichardt's theory for free turbulent flows. The acoustic radiation from each of the sound sources is evaluated from high-frequency asymptotic solutions of Lilley's equation. The jet plume is subdivided into several hundred elemental volume sources, each roughly the size of a turbulent eddy volume. The correlated sound level spectra of the individual eddy volumes are summed on a mean-square pressure basis to yield the total turbulent mixing noise levels. An auxiliary calculation of shock-cell broadband noise is made and added to the turbulent mixing noise spectrum to give the total farfield noise. A description of the computational model and associated computer program is presented herein, along with a sample of input and output. A FORTRAN listing of the computer program is also included.					
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# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
sq in	square inches	6.5	square centimeters	cm <sup>2</sup>
sq ft	square feet	0.09	square meters	m <sup>2</sup>
sq yd	square yards	0.8	square meters	m <sup>2</sup>
sq mi	square miles	2.6	square kilometers	km <sup>2</sup>
acres	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<b>VOLUME</b>				
teaspoon	teaspoons	5	milliliters	ml
tablespoon	tablespoons	15	milliliters	ml
fluid ounce	fluid ounces	30	milliliters	ml
cup	cups	0.24	liters	l
pint	pints	0.47	liters	l
quart	quarts	0.95	liters	l
gallon	gallons	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m <sup>3</sup>
cu yd	cubic yards	0.76	cubic meters	m <sup>3</sup>

## TEMPERATURE (exact)

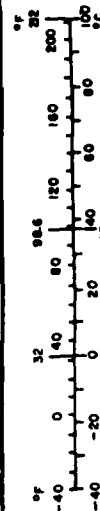
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C
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## Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
km	kilometers	1.1	miles	mi
		0.6	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
km <sup>2</sup>	square kilometers	0.4	square miles	mi <sup>2</sup>
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	acres
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m <sup>3</sup>	cubic meters	35	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>

## TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F
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\* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Spec. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13 10 286.

## PREFACE

This report describes the work performed under Task 2 of the DOT/FAA High Velocity Jet Noise Source Location and Reduction program (Contract DOT-OS-30034). The objectives of the program were:

- Investigation of the aerodynamic and acoustic mechanisms of various jet noise suppressors, including scaling effects
- Analytical and experimental studies of the acoustic source distribution in such suppressors, including identification of source location, nature and strength and noise reduction potential
- Investigation of inflight effects on the aerodynamic and acoustic performance of these suppressors.

The results of these investigations lead to the preparation of a design guide report for predicting the overall characteristics of suppressor concepts from models to full-scale static, to inflight conditions, as well as a quantitative and qualitative prediction of the phenomena involved.

The work effort in this program was organized under the following major Tasks, each of which is reported in a separate final report:

- Task 1 - Activation of Facilities and Validation of Source Location Techniques.
- Task 2 - Theoretical Developments and Basic Experiments.
- Task 3 - Experimental Investigation of Suppression Principles.
- Task 4 - Development and Evaluation of Techniques for Inflight Investigation.
- Task 5 - Investigation of Inflight Aero-Acoustic Effects on Suppressed Exhausts.
- Task 6 - Preparation of Noise Abatement Nozzle Design Guide Report.

Task 1 was an investigative and survey effort designed to identify acoustic facilities and test methods best suited to jet noise studies. Task 2 was a theoretical effort complemented by theory verification experiments which extended across the entire contract period of performance.

This volume is a supplement to the Task 2 report, documenting a general method for predicting the aerodynamic and acoustic behavior of turbulent jets. The objective of the report is to provide users with a description of the method and associated computational procedure in sufficient detail that it can be implemented and utilized as a useful engineering tool.

Task 3 represented a substantial contract effort to gather various test data on a wide range of high velocity jet nozzle suppressors. These data, intended to help identify several "optimum" nozzles for inflight testing under Task 5, provide an extensive high quality data bank useful to preparation of the Task 6 design guide as well as to future studies.

Task 4 was similar to Task 1, except that it dealt with the specific test facility requirements, measurement techniques and analytical methods necessary to evaluate the inflight noise characteristics of simple and complex suppressor nozzles. This effort provided the capability to conduct the "flight" effects test programs of Task 5.



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# SYMBOLS

$A_j$	- jet nozzle exhaust area
AR	- outer-to-inner stream area ratio
$a_{xx}$	- (x-x) quadrupole directivity factor
$a_{xy}$	- (x-y) quadrupole directivity factor
$a_{yy}$	- (y-y) quadrupole directivity factor
$a_{yz}$	- (y-z) quadrupole directivity factor
$b_h$	- enthalpy mixing layer thickness
$b_m$	- momentum mixing layer thickness
C	- convective amplification factor
$C_h$	- enthalpy mixing layer spreading parameter
$C_j$	- jet exit plane speed of sound
$C_m$	- momentum mixing layer spreading parameter
$C_a$	- ambient speed of sound
$C_p$	- specific heat at constant pressure
$C_1$	- empirical constant in spreading parameter equation
$C_2$	- empirical constant in spreading parameter equation
$D_{eq}$	- equivalent area nozzle diameter $\sqrt{4A_j/\pi}$
$D_h$	- nozzle hydraulic diameter $4A_j/P_w$
f	- observed frequency
$f_p$	- peak-noise observed frequency
$g^2(r)$	- shielding function
H	- stagnation enthalpy relative to ambient
$I(\Omega)$	- source intensity spectrum
k	- source wave number $\Omega/C_a$
$L_{avg}$	- average shock cell spacing
M	- flow Mach number $U/C_a$
$M_a$	- ambient (windtunnel or flight) Mach number
$M_c$	- eddy convection Mach number $U_c/C_a$
$M_j$	- jet nozzle exit plane Mach number $U_j/C_a$ (also $U_j/C_j$ for shock noise prediction)
$M_m$	- postmerged region potential core Mach number
$M_o$	- Mach number at source location, $M(r_o)$
N	- number of shock cells
OASPL	- overall sound pressure level, dB re 0.0002 $\mu$ -bar

PNL	- perceived noise level, dB re 0.0002 $\mu$ -bar
PR	- nozzle stagnation-to-ambient static pressure ratio
PWL	- power watt level, dB re $10^{-13}$ watts
$P_w$	- wetted perimeter of nozzle contour
$p_a$	- ambient static pressure
$\overline{p^2}$	- mean-square acoustic pressure
R	- source-to-observer distance
$R_o$	- flow field calculation transverse coordinate
$R_g$	- gas constant (1716 $\text{lb}_f\text{-ft/slug-}^\circ\text{R}$ )
r	- radial coordinate
$r_b(x)$	- centerbody radius
$r_o$	- radial source location
$r_\sigma$	- radial turning point location
SPL	- sound pressure level, dB re 0.0002 $\mu$ -bar
$SPL_p$	- peak value of SPL 1/3-octave spectrum
T	- flow static temperature
$T_a$	- ambient static temperature
$T_T$	- flow stagnation temperature
$T_{Tj}$	- nozzle exit jet stagnation temperature
TR	- outer-to-inner stream temperature ratio
U	- local mean flow velocity
$U_a$	- ambient (wind-tunnel or flight) velocity
$U_c$	- eddy convection speed
$U_j$	- jet exit plane velocity
$U_m$	- postmerged potential core velocity
$U_o$	- mean flow velocity at source location
$u'$	- axial turbulence velocity (r.m.s. intensity)
$V_j$	- ideally expanded jet velocity
VR	- outer-to-inner stream velocity ratio
x	- axial coordinate
y	- vector location of eddy volume in jet
$\alpha$	- coefficient in acoustic calculation; also angular coordinate of nozzle boundary contour
$\alpha_t$	- turbulent decay parameter in convective amplification factor

$\beta$	- shock strength parameter
$\beta_{xx}$	- (x-x) quadrupole shielding factor
$\beta_{xy}$	- (x-y) quadrupole shielding factor
$\beta_{yy}$	- (y-y) quadrupole shielding factor
$\beta_{yz}$	- (y-z) quadrupole shielding factor
$\beta_{01}$	- shielding factor for case (c)
$\beta_{02}$	- shielding factor for case (e)
$\beta_{12}$	- shielding factor for case (f)
$\beta_t$	- axial shear stress weighting factor
$\gamma$	- ratio of specific heats
$\Delta r$	- transformed radial coordinate
$\Delta v$	- transformed boundary radius
$\delta_t$	- aximuthal shear stress weighting factor
$\theta$	- observer angle relative to jet axis
$\theta_i$	- observer angle relative to inlet axis, $\theta_i = 180^\circ - \theta$
$\mu_t$	- characteristic time-delay azimuthal weighting factor
$v_o$	- radial coordinate of nozzle boundary contour
$\rho$	- flow mean density
$\rho_a$	- ambient density
$\rho_j$	- jet exit plane density
$\tau_o$	- characteristic time-delay
$\tau_x$	- axial shear stress
$\tau_r$	- radial shear stress
$\tau_\phi$	- azimuthal shear stress
$\Phi$	- flow field calculation azimuthal coordinate
$\phi$	- azimuthal angular coordinate
$\psi$	- enthalpy function
$\Omega$	- source radian frequency
$\omega$	- observer radian frequency

#### Subscripts

a	- ambient condition
ann	- referring to annulus property
b	- centerbody parameter

c	- convection property
eq	- equivalent condition
g	- gas property
h	- referring to enthalpy or heat transport
i	- referring to component in i-direction; also, referenced to inlet axis
j	- referring to jet exit plane condition
m	- referring to momentum transport; also, postmerged condition
o	- referring to source location condition
p	- peak noise value
r	- radial component
T	- stagnation condition
t	- referring to a turbulence parameter
x	- axial component
xx	- referring to (x-x) quadrupole property
xy	- referring to (x-y) quadrupole property
yy	- referring to (y-y) quadrupole property
yz	- referring to (y-z) quadrupole property
$\sigma$	- referring to turning point property
$\phi$	- azimuthal component

## 1.0 SUMMARY

This report represents a supplemental Task 2 effort under Contract DOT-OS-30034 documenting the computerized jet noise prediction method. A complete description of the computer program is provided, including examples of input preparation, output cases, and a listing of the FORTRAN computer code. The mathematical model is briefly summarized (it appears in detail in the Task 2 report proper).

A unified aerodynamic/acoustic prediction technique has been developed for assessing the noise characteristics of suppressor nozzles. The technique utilizes an extension of Reichardt's method to provide predictions of the jet plume flow field (velocity, temperature and turbulence intensity distributions). The turbulent fluctuations produced in the mixing regions of the jet are assumed to be the primary source of noise generation, as in the classical theories of jet noise. The alteration of the generated noise by the jet plume itself as it propagates through the jet to the far-field observer (sound/flow interaction or fluid shielding) is modelled utilizing the high-frequency shielding theory based on Lilley's equation.

These basic modelling elements (flow field prediction turbulent mixing noise generation, and sound/flow interaction) have been coupled together in a discrete volume-element formulation. The jet plume is divided into elemental volumes, each roughly the size of a representative turbulence correlation volume appropriate to that particular location in the plume. Each volume element is assigned its own characteristic frequency, spectrum, and acoustic intensity. The sound/flow interaction effects for each volume element are evaluated from the flow environment of the element. The individual volume elements are assumed to be uncorrelated with each other, so that the total contribution to the far field is simply the sum of the individual volume element contributions.

The aero-acoustic model discussed herein is directed toward prediction of high velocity jet noise (1500 - 3000 feet per second), for arbitrary nozzle shapes, including sound pressure level spectra at any observer location.

The model in its present form does have certain limitations. For multielement configurations, all elements must be parallel and non-impinging. In addition, the flow field calculation assumes constant static pressure mixing, so that multichute or multitube nozzles with significant base pressure variations will not be properly simulated. This limitation is important for closely-spaced nozzle elements. Finally, the shock-cell noise portion of the prediction is likely to be inadequate for multielement and/or multiflow configurations.



## 2.0 INTRODUCTION

Many jet noise suppressor nozzles have been designed utilizing intuitive notions of how to suppress jet noise, and have demonstrated substantial noise reduction, although often at the expense of considerable thrust loss, increased engine weight, manufacturing cost and complexity. Seemingly minor changes in suppressor nozzle design, for the purpose of improving thrust performance, often result in substantial loss of noise suppression. It is therefore highly desirable to have available a quantitative prediction technique for estimating the aerodynamic and acoustic characteristics of suppressor-type nozzle configurations, so that design and optimization studies can be made prior to construction and testing in order to minimize the time and cost of development. This technique should ideally be sensitive to the controllable design variables, and should be based on a minimum of empiricism. Any empiricism employed should be tied more or less to physical (flow and acoustic propagation) characteristics rather than geometric parameters, i.e., it should be "universal" in a normalized (but perhaps restricted) sense.

Previous work on modelling of jet aero-acoustic characteristics has been confined to simple round and coannular jets. One of the first attempts at developing a comprehensive aerodynamic acoustic jet model was published by Lee, Kendall, et al., Reference (1), and Grose and Kendall, Reference (2). This approach utilized an extension of Reichardt's method for predicting the jet flow properties (this method is adopted herein and in Reference 3) for round and lobe-type nozzles. Acoustic power spectra are predicted in Reference (1) and (2), based on a "slice-of-jet" model wherein the power per axial slice is computed and related to a certain frequency band by means of empirically-derived frequency versus axial distance relations. Successful predictions are confined to low Mach numbers. A volume-element summation ("lump-of-jet") approach was first developed by Benzakein et al., Reference (4), for round and coannular jets. A finite-difference turbulent-kinetic-energy model was developed therein to predict the jet flow field, while the classical Lighthill (5) and Ffowcs-Williams (6) formulations were employed, with suitable empirical modifications, to predict the noise from each volume element. Extensions of the method of Benzakein et al. (4) to distinguish between self-noise and shear-noise, proposed by Jones (7) and Ribner (8), were developed by Knott (9) and Moon (10). Recently, Chen (11) has applied Kendall's method (2) to predicting power spectra of coannular jets.

The above methods either ignore the sound/flow interaction effects completely, or recognize only source convection in absence of a shrouding flow, which has been shown to give incorrect simulation (see Mani, Reference 12) for all but the lowest jet velocities, especially when predicting sound pressure level spectra at observer angles close to the jet axis. The aero-acoustic model discussed in this report is directed toward prediction of high velocity jet noise (1500 - 3000 fps), for arbitrary nozzle shapes, including sound pressure level spectra at any observer location.

Section 3 summarizes the mathematical model (which is presented in detail in Reference 3) and Section 4 describes the computer program. A description of inputs to the computer program is presented in Appendix A and a description of the outputs is presented in Appendix B. Appendices C and D contain a sample output and a computer source listing for the program, respectively.

### 3.0 ANALYSIS

#### 3.1 OUTLINE OF METHOD

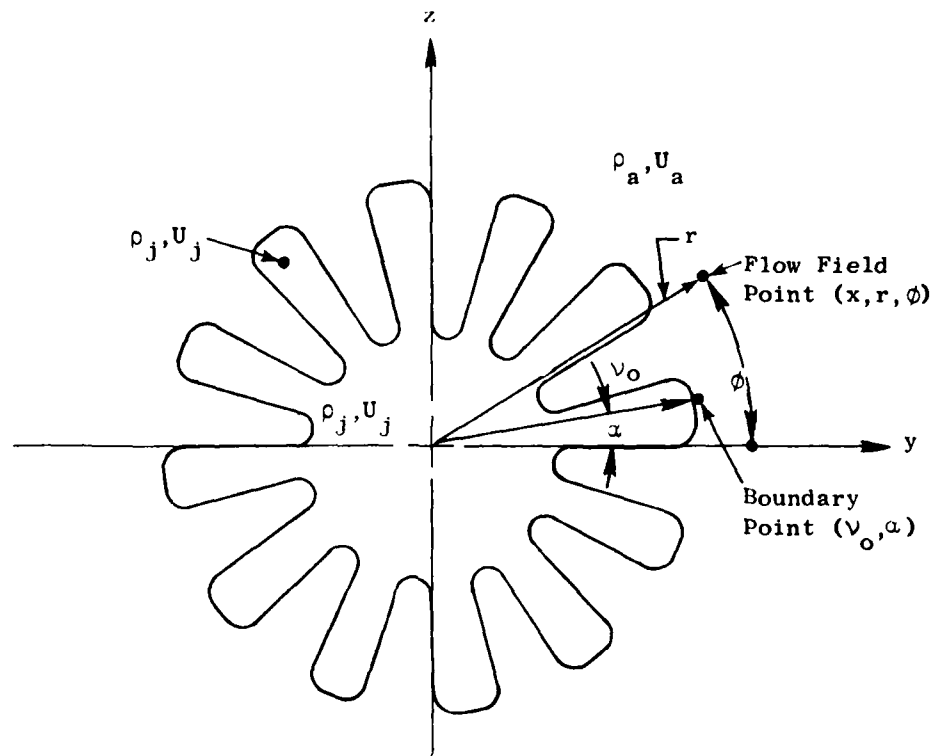
Consider a jet plume exhausting from a nozzle of arbitrary shape, as shown in Figure 1. Utilizing the modified Reichardt theory described in Reference (3), the mean velocity, temperature, density and turbulent shear stress distributions can be computed throughout the jet plume. The required inputs are nozzle shape, nozzle exit plane total pressures and temperatures, and ambient total and static pressures and temperatures.

The jet plume is subdivided into elemental volumes which are approximately the size of a typical turbulent correlation volume or "eddy size". The modified Reichardt theory can provide the aerodynamic properties at any arbitrary point in the plume because of the closed-form solution formulation (the calculation is not a finite-difference method whose grid points are established/ dictated by the accuracy/stability requirements of the numerical procedure). The flow properties are therefore computed at the geometric centers of these eddy volume elements.

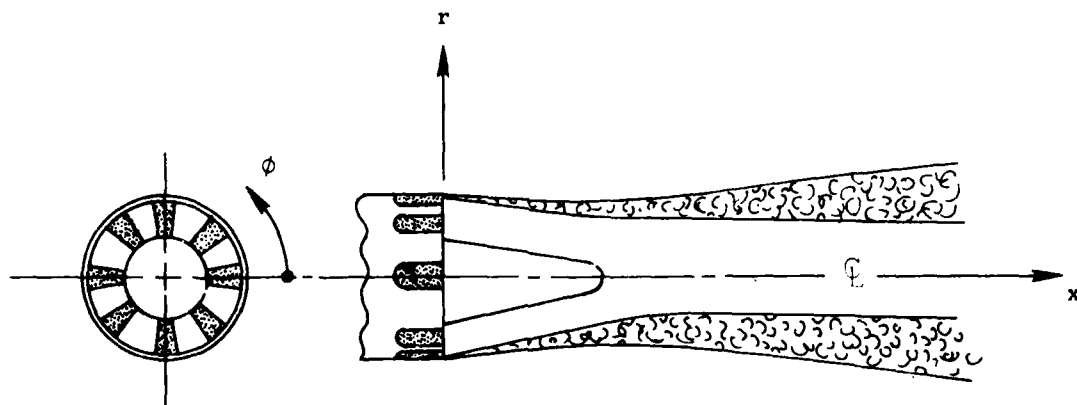
The noise generated by each of the volume elements is estimated from the classical Lighthill (5) expressions for noise produced by free turbulence, assuming that the turbulence can be modeled as locally-isotropic, convecting quadrupole sources of sound, as proposed by Ribner (8). The turbulent structure parameters (intensity, length-scale, characteristic frequency, spectrum) required for computing the generated noise are derived from the calculated mean-flow distributions using previously established empirical similarity relations, developed by Davies et al. (13).

For each volume element, the effect of convection and fluid shielding on the emitted sound of that element is computed. The flow properties in the vicinity of the element, i.e., mean velocity profiles and temperature profiles, determine the amount of flow shrouding or fluid shielding seen by that element. From the generated noise spectrum and the predicted convection and fluid shielding, the net emitted noise level, at each observer angle and 1/3-octave band frequency of interest, is calculated. The contributions from each volume element in the jet are summed on a mean-square pressure basis, assuming that individual volume elements are uncorrelated with each other, to provide the total 1/3-octave spectrum observed in the far field sound pressure.

A typical example of how a jet plume is subdivided into "eddy" volume elements is illustrated in Figure 2. The subdivisions are very small close to the nozzle exit plane where the turbulence length-scales are small, and the volume elements are made progressively larger in the downstream direction, simulating the increasing length-scale with downstream distance.



(b) Typical Suppressor Nozzle Exit Plane Planform Shape and Nomenclature



(a) Jet Plume Coordinate System

Figure 1. Typical Jet Plume Exhausting from a Nozzle of Arbitrary (Noncircular) Planform Shape.

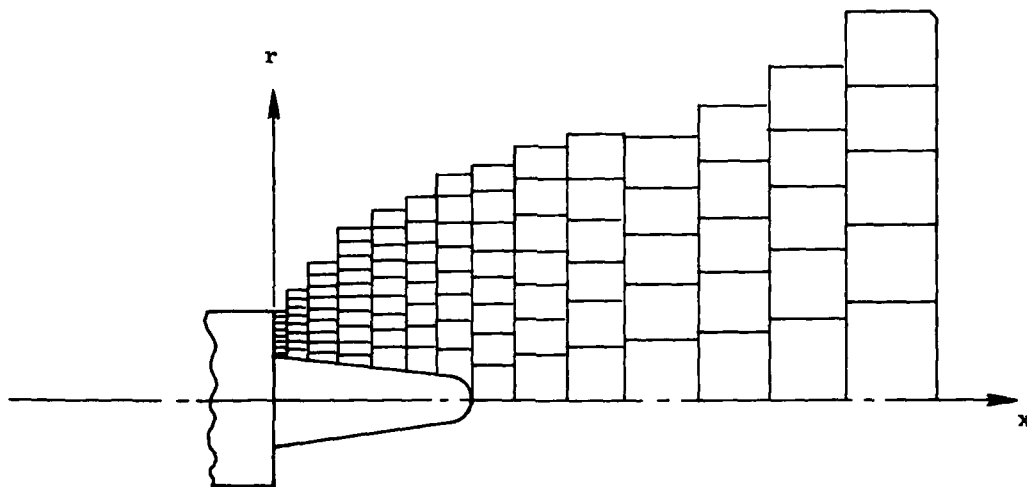


Figure 2. Typical Jet Plume Flow Field Subdivision (Not to Scale) into Eddy Volume Elements.

In addition to the calculation of turbulent mixing noise, the shock-cell broadband noise is also computed using a modification of the Harper-Bourne/Fisher method, Reference (14), as described in Reference (3). The mixing noise spectra and the shock-cell noise spectra are summed on a mean-square pressure basis to yield the total jet noise spectra, at each far-field observer angle.

A block diagram of the computation sequence for the jet noise prediction just described is shown in Figure 3. Note also that atmospheric attenuation corrections, using the method of Reference (15), are made to the predicted spectra to account for air attenuation at the appropriate far-field distance. From the far-field sound pressure spectra, the overall sound pressure levels (OASPL), perceived noise levels (PNL) and sound power spectrum (PWL) are also evaluated.

### 3.2 FLOW FIELD PREDICTION

The jet plume flow field is computed using the extension of Reichardt's method developed in Reference (3). The method basically consists of predicting the diffusive transport of momentum flux and enthalpy flux from a specified exit plane distribution to various axial stations along the plume. In addition, the various components of turbulent shear stress are also calculated, being related to directional derivatives of the axial component of momentum flux. From these distributions, the mean axial velocity, density and turbulence intensity distributions are estimated.

A typical suppressor nozzle planform shape at the nozzle exit plane is shown in Figure 1. The nozzle contour can be defined by coordinates  $(v_o, \alpha)$ . The jet nozzle exit plane conditions are denoted by subscript "j", and ambient field (external flow) conditions by subscript "a". The flow conditions at any flow field point  $(x, r, \phi)$  are computed from the following equations, taken from Reference (3):

#### Momentum Transport:

$$\rho U^2 - \rho_a U_a^2 = \frac{1}{2\pi} \int (\rho_j U_j^2 - \rho_a U_a^2) \left[ 1 - e^{-R_o^2/b_m^2} \right] d\phi \quad (1)$$

#### Heat Transport:

$$\rho UH = \frac{1}{2\pi} \int (\rho_j U_j H_j) \left[ 1 - e^{-R_o^2/b_h^2} \right] d\phi \quad (2)$$

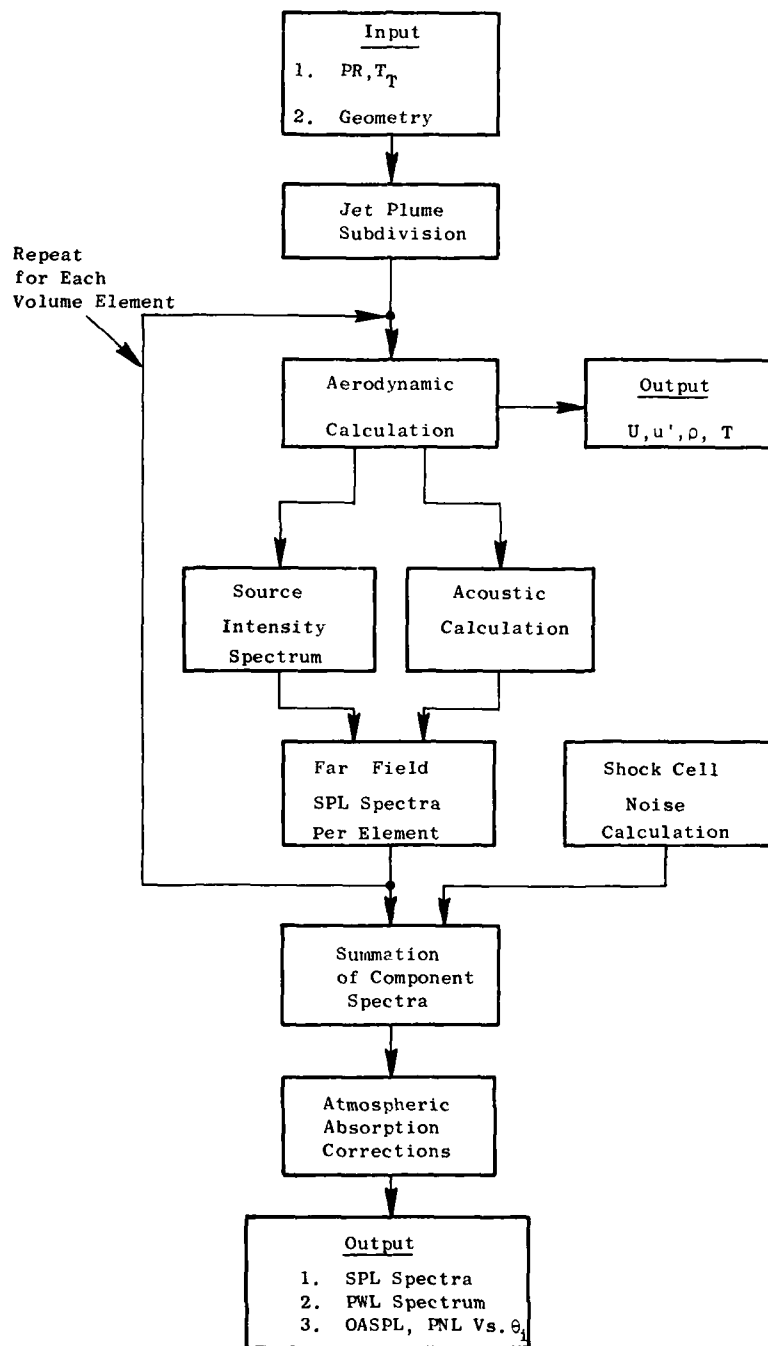


Figure 3. Block Diagram of Jet Noise Aeroacoustic Prediction Model.

Shear Stresses:

$$\frac{\tau_x}{\rho} = -\frac{C_m^2}{2\pi} \int (U_j^2 - U_a^2) \left[ \frac{R_o^2}{b_m^2} e^{-R_o^2/b_m^2} \right] d\phi \quad (3)$$

$$\frac{\tau_r}{\rho} = \frac{C_m}{2\pi} \int (U_j^2 - U_a^2) \left[ \frac{\sqrt{\pi}}{2} \operatorname{erf} \left( \frac{R_o}{b_m} \right) - \frac{R_o}{b_m} e^{-R_o^2/b_m^2} \right] \times \cos \phi d\phi \quad (4)$$

$$\frac{\tau_\phi}{\rho} = \frac{C_m}{2\pi} \int (U_j^2 - U_a^2) \left[ \frac{\sqrt{\pi}}{2} \operatorname{erf} \left( \frac{R_o}{b_m} \right) - \frac{R_o}{b_m} e^{-R_o^2/b_m^2} \right] \times \sin \phi d\phi \quad (5)$$

where  $\int$  denotes a contour integral around the nozzle planform boundary.

In the above equations,  $U$ ,  $\rho$ , and  $H$  are the mean velocity, density and enthalpy, respectively, and  $\tau_x$ ,  $\tau_r$  and  $\tau_\phi$  are the  $x$ ,  $r$  and  $\phi$  - components of turbulent shear stress. The coordinates  $R_o$  and  $\phi$  are defined by the relations

$$\left. \begin{aligned} R_o^2 &= (r - v_o)^2 + 2rv_o [1 - \cos(\phi - \alpha)] \\ \text{and } R_o \cos \phi &= r - v_o \cos(\phi - \alpha) \end{aligned} \right\} \quad (6)$$

The turbulent mixing length parameters  $b_m = C_m x$  and  $b_h = C_h x$  are determined by the momentum spreading rate parameter  $C_m$  and enthalpy spreading parameter  $C_h$ . Empirical expressions for these have been developed in Reference (3), and are as follows:

$$C_m = \frac{0.075}{(1 + C_1 VR)(1 + C_2 M_j)} \quad , \quad C_h = 1.15 C_m \quad (7)$$



where  $VR = U_a/U_j$  and  $M_j = U_j/C_j$ , the jet exit Mach number. The constants  $C_1$  and  $C_2$  were determined from calibrations with conical nozzle flow field velocity measurements, and values of  $C_1 = 0.25$  and  $C_2 = 0.08$  were found to give the best agreement with experiments.

The velocity and density are determined from the distributions of  $(\rho U^2)$  and  $(\rho UH)$  from the following expressions:

$$U = \frac{\rho UH}{2\psi} + \sqrt{\left(\frac{\rho UH}{2\psi}\right)^2 + \frac{C_p T_a (\rho U^2)}{\psi}} \quad (8)$$

$$\text{where} \quad H = C_p T + \frac{1}{2} \rho U^2 - C_p T_a \quad (9)$$

$$\text{and} \quad \psi = \frac{\gamma}{\gamma-1} p + \frac{1}{2} (\rho U^2) \quad (10)$$

$$\text{and} \quad \rho = \frac{(\rho U^2)}{U^2} ; \quad T = \frac{p}{\rho R_g} \quad (11)$$

In the above expressions,  $C_p$  and  $R_g$  are the specific heat at constant pressure and universal gas constant, respectively ( $R_g = \gamma C_p / (\gamma-1)$ ),  $\gamma$  is the ratio of specific heats, and  $p$  is the jet static pressure, assumed to be equal to the ambient static pressure. The local temperature is  $T$ , and  $T_a$  is the ambient static value.

The axial turbulence intensity  $u'$  is computed from the shear stress components utilizing the following expression:

$$(u')^2 = \sqrt{(\tau_r/\rho)^2 + \delta_t (\tau_\phi/\rho)^2 + \beta_t (10 \tau_x/\rho)^2} \quad (12)$$

where  $\delta_t$  and  $\beta_t$  are empirically - determined constants.

Modifications to the above computation procedure are developed in Reference (3) for nozzles with an axisymmetric centerbody or plug. This modification consists of a coordinate transformation of the variables ( $R_0$ ,  $\phi$ ) as follows:

$$\begin{aligned}
R_o^2 &= (\Delta r - \Delta v)^2 + 2\Delta r \Delta v [1 - \cos(\phi - \alpha)] \\
R_o \cos \phi &= \Delta r - \Delta v_o \cos(\phi - \alpha) \\
\text{where } \Delta r &= \sqrt{r^2 - r_b^2(x)} \quad \text{and} \quad \Delta v = \sqrt{v_o^2 - r_b^2(o)}
\end{aligned} \quad (13)$$

and  $r_b(x)$  is the centerbody/plug contour coordinate specification. For  $r_b(x) = 0$ , Equation (13) reduce to Equation (6).

Equations (1) through (13) completely define the flow field calculation procedure. As discussed in the previous section, the flow properties are evaluated at all field points corresponding to eddy volume element centers  $(x, r, \phi)$

### 3.3 TURBULENT MIXING NOISE PREDICTION

Expressions are developed in Reference (3), for the far-field noise of convected quadrupoles imbedded in a parallel shear flow, utilizing high-frequency asymptotic solutions to Lilley's equation. These expressions, for a source of unit volume and unit strength, when applied to a collection of sources distributed throughout a parallel shear flow model of the jet plume, yield the following equation for the far-field noise spectrum:

$$\overline{p^2}(R, \theta, \Omega) = \int_{\vec{y}} \alpha (a_{xx} + 4a_{xy} + 2a_{yy} + 2a_{yz}) d\vec{y} \quad (14)$$

where  $\int ( ) d\vec{y}$  implies integration over the entire jet plume. The factors  $a_{xx}$ ,  $a_{xy}$ ,  $a_{yy}$  and  $a_{yz}$  are the directivity factors for each of the contributing quadrupole types contained in each turbulent eddy volume element. The factor  $\alpha$  is given by

$$\alpha = \frac{I(\Omega)}{16\pi^2 R^2 C_a^4} \left( \frac{\rho a}{\rho_o} \right)^2 \left( \frac{C_a}{C_o} \right)^2 (1 - M_o \cos \theta)^{-2} (1 - M_c \cos \theta)^{-2} \quad (15)$$

where  $I(\Omega)$  is given by

$$I(\Omega) = \rho_o^2 (u')^7 (\Omega \tau_o)^4 \exp \left[ -\frac{1}{8} (\Omega \tau_o)^2 \right] \quad (16)$$

and  $\tau_o$  is the two-point velocity correlation characteristic time delay.

Subscript "o" refers to the volume-element or eddy-center location conditions. The parameters  $M_o$  and  $M_c$  are defined as

$$M_o = U_o / C_a \quad M_c = U_c / C_a$$

where  $U_c$  is the effective convection velocity of the eddy.

The directivity factors  $a_{xx}$ ,  $a_{xy}$ ,  $a_{yy}$  and  $a_{yz}$  have different forms, depending on the location of the source and the velocity and temperature profiles in the vicinity of the source. As discussed in Reference (3), these factors depend explicitly upon a shielding function  $g^2$ , which has the form

$$g^2(r) = \frac{(1 - M \cos \theta)^2 (C_a/C)^2 - \cos^2 \theta}{(1 - M_c \cos \theta)^2} \quad (17)$$

where  $C=C(r)$  and  $M=M(r)/C_a$ . Given a velocity  $U(r)$  and temperature profiles  $C(r) \sim \sqrt{T(r)}$ , the shielding function profile can be computed per Equation (17). Depending on the observer angle  $\theta$  and the profile shapes, the profile of  $g^2(r)$  may have both positive and negative "zones", or may be positive for all values of  $r$ . If a negative region exists, then the possibility of fluid shielding of the sound source exists, depending on the location of the source relative to the negative or shielding zone. The location  $r=r_o$  where  $g^2(r)$  crosses zero is termed a turning point; practically speaking, more than one turning point can occur, although more than two turning points is very rare.

A maximum of two turning points is considered herein. This allows six possible situations regarding the source location relative to a shielding zone. These are illustrated qualitatively in Figure 4. This figure shows  $g^2(r)$  plotted versus radial distance in the jet plume for six cases. In case (a),  $g^2(r)$  is positive for all values of  $r$ , so no shielding of the source occurs no matter where it is located radially in the jet. In case (b), the source is located outboard of the region where  $g^2(r)$  is negative, so still no shielding occurs. In case (c), however, the source is located inboard of the turning point,  $r_o < r_{o1}$ , and lies inside the shielding zone. The source will therefore be shielded to some extent.

In cases (d,e,f) shown in Figure 4, there are two turning points  $r_{o1}$  and  $r_{o2} > r_{o1}$ . In case (d), the source lies outside of both turning points and therefore sees no shielding. In case (e), the source lies between the two turning points and thus is shielded by the fluid layer between  $r=r_o$  and  $r=r_{o2}$ .

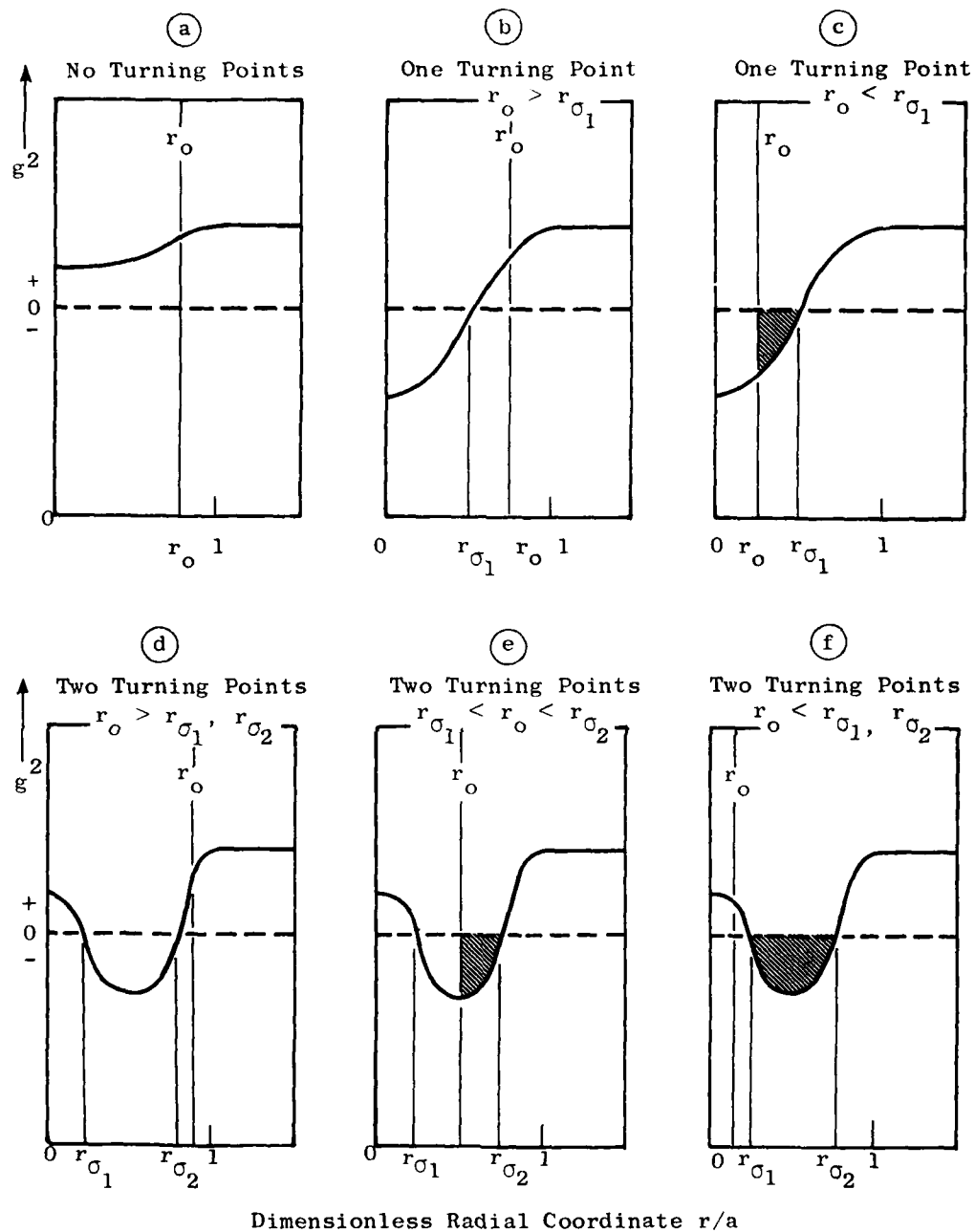


Figure 4. Possible Solution Types for a Maximum of Two Turning Points. Shaded Areas Denote Shielding of Source.

The acoustic radiation solutions for all of the six cases illustrated in Figure 4 are worked out in detail in References (3), and yield different forms for the directivity factors  $a_{xx}$ ,  $a_{xy}$ ,  $a_{yy}$  and  $a_{yz}$  for each case. These directivity factors have the following forms:

$$a_{xx} = \frac{\cos^4 \theta}{(1-M_c \cos \theta)^4} \beta_{xx} \quad (18a)$$

$$a_{xy} = \frac{g_o^2 \cos^2 \theta}{2(1-M_c \cos \theta)^2} \beta_{xy} \quad (18b)$$

$$a_{yy} = \frac{3}{8} g_o^4 \beta_{yy} \quad (18c)$$

$$a_{yz} = \frac{1}{8} g_o^4 \beta_{yz} \quad (18d)$$

where  $g_o^2$  is the value of  $g^2(r)$  at the source radius  $r=r_o$ . The shielding coefficients  $\beta_{xx}$ ,  $\beta_{xy}$ ,  $\beta_{yy}$  and  $\beta_{yz}$  depend upon the case encountered in Figure 4. If the parameters  $\beta_{01}$ ,  $\beta_{02}$  and  $\beta_{12}$  are defined as

$$\beta_{01} = \exp \left\{ -2k \int_{r_o}^{r_{\sigma 1}} |g^2(r)|^{1/2} dr \right\} \quad (19a)$$

$$\beta_{02} = \exp \left\{ -2k \int_{r_o}^{r_{\sigma 2}} |g^2(r)|^{1/2} dr \right\} \quad (19b)$$

$$\beta_{12} = \exp \left\{ -2k \int_{r_{\sigma 1}}^{r_{\sigma 2}} |g^2(r)|^{1/2} dr \right\} \quad (19c)$$

where  $k=\Omega/C_a$ , the shielding coefficients are then determined from the following table:

Table 1. Shielding Coefficients  $\beta_{ij}$ .

Case	$\beta_{xx}$	$\beta_{xy}$	$\beta_{yy}$	$\beta_{yz}$
a	1	1	1	1
b	1	1	1	1
c	$\beta_{01}$	0	0	0
d	1	1	1	1
e	$\beta_{02}$	0	0	0
f	$\beta_{12}$	$\beta_{12}$	$\beta_{12}$	$\beta_{12}$

Note that a value of  $\beta_{xx}$ , etc., of unity indicates no fluid shielding, as in cases (a), (b) and (d). When the source is imbedded within the shielding zone, as in cases (c) and (e), only the x-x quadrupole contributes, for reasons explained in Reference (3).

#### 3.4 SHOCK-CELL NOISE PREDICTION

As discussed in Section 3.1, the shock cell broadband noise prediction is based on a modification of the theory of Harper-Bourne and Fisher (14). A thorough discussion of this theory and its application to noncircular nozzles can be found in Reference (3).

Although the analysis of Reference (3) demonstrated that noncircular nozzle shock-cell noise exhibits the same scaling of noise level with operating conditions as that for a conical nozzle, the influence of nozzle shape on noise level and spectrum shape was not quantified to the extent that a verified prediction method could be established. A method for predicting the shock cell structures (number of cells, spacing, etc.) is still required before a general shock noise prediction procedure can be established. An interim shock cell noise prediction method was therefore adopted for incorporation into the unified aeroacoustic prediction model, with the expectation of replacement by a more general method at some future date.

The interim method is essentially that of Deneuille (16), with some modifications to simplify the calculation and incorporate some of the ideas developed in Reference (3). The method consists of modeling the shock cell noise component of the spectrum by two straight lines, as illustrated in Figure 5. The primary variables required are peak sound pressure level  $SPL_p$  and the frequency  $f_p$  at which this occurs.

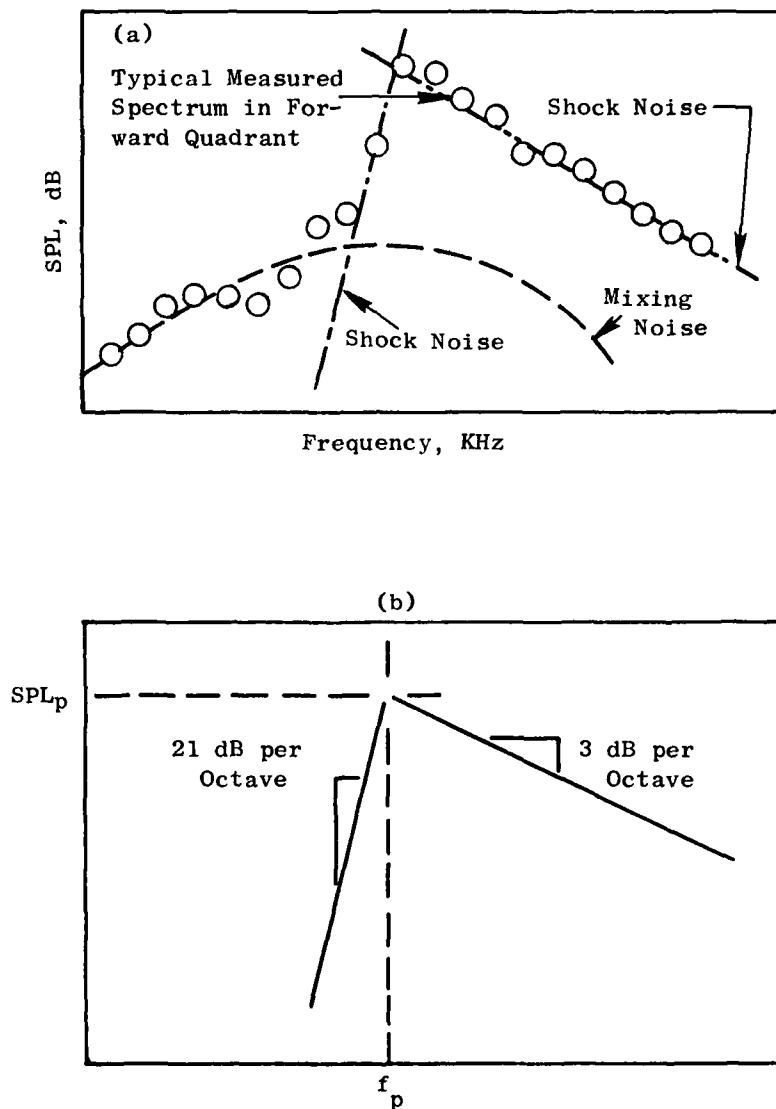


Figure 5. Empirical Model of Shock Cell Noise Component of Spectrum: (a) Shock Cell Component Approximated by Straight Lines; (b) Model Representation of Shock Cell Spectrum and Correlation Parameters.

Given a nozzle operating at pressure ratio PR, jet velocity  $V_j$ , having total flow area  $A_j$ , equivalent diameter  $D_{eq} = \sqrt{4A_j/\pi}$ , and hydraulic diameter  $D_h = 4A_j/P_w$  (where  $P_w$  is the nozzle boundary wetted perimeter), the parameters  $SPL_p$  and  $f_p$  can be computed as a function of observer angle  $\theta_i$ . The computation proceeds as follows:

- (1) compute shock strength parameter  $\beta$  from

$$\beta = \sqrt{M_j^2 - 1} \quad (20)$$

where

$$M_j^2 = \frac{2}{\gamma - 1} \left[ PR \frac{\gamma - 1}{\gamma} - 1 \right] \quad (21)$$

- (2) compute average shock-cell spacing  $L_{avg}$  from

$$L_{avg} = 1.1 \beta D_{eq} \quad (22)$$

- (3) Compute peak noise frequency from

$$f_p = \frac{U_c}{L_{avg}} (1 + M_c \cos \theta_i)^{-1} \quad (23)$$

where  $U_c = 0.7 U_j$  and  $M_c = U_c/C_a$ .

- (4) Compute peak SPL from

$$\begin{aligned} SPL_p(\theta_i) = & 152.6 + 40 \log_{10}(\beta) + 10 \log_{10}(A_j/R^2) \\ & + 10 \log_{10}(D_h/D_{eq}) - 40 \log_{10}(1 - M_a \cos \theta_i) \\ & + 10 \log_{10}(N/8) \end{aligned} \quad (24)$$

where  $M_a = U_a/C_a$ , the flight Mach number, and  $N$  is the number of shock cells (usually  $N = 8$  is assumed). The spectrum shape is then calculated from the assumed two straight-line model shown in Figure 5. The equations are as follows:

$$\left. \begin{aligned} SPL(f, \theta_i) &= SPL_p(\theta_i) - 10 \log_{10}(f/f_p), \quad f > f_p \\ SPL(f, \theta_i) &= SPL_p(\theta_i) + 70 \log_{10}(f/f_p), \quad f < f_p \end{aligned} \right\} \quad (25)$$



Equations (20 through 25) completely describe the shock cell noise prediction method for obtaining 1/3-octave spectra at any observer angle  $\theta_1$ .

### 3.5 AEROACOUSTIC MODEL INTEGRATION

An outline of the basic prediction method and a description of the component building blocks have been presented in the preceding sections. This section describes how these building blocks are tied together. Additionally, some practical guidelines are given which were found from experience to be helpful in producing reasonably accurate predictions while maximizing computational efficiency.

The mixing noise spectrum is computed from equation (14), with the integration over the jet plume  $\int ( ) d\vec{y}$  replaced (or approximated) by a summation over all eddy-volume elements. Since equation (14) represents the narrowband spectrum in terms of source frequency  $\Omega$  (emitted frequency in a reference frame moving with the eddy), a conversion is made to 1/3-octave spectrum based on observed center frequency  $f$ . It is assumed that the 1/3-octave band level can be approximated by the narrowband level evaluated at the center frequency, multiplied by the bandwidth, rather than integrating the narrowband level distribution over the bandwidth. The standard 1/3-octave center frequencies are used. For each eddy-volume element, at each observer angle  $\theta_1 = 180^\circ - \theta$ , the source frequency is calculated for each 1/3-octave center frequency from the relation

$$\Omega = 2\pi f(1-M_c \cos \theta) \quad (26)$$

The spectrum shape of a given eddy, equation (16), determines the amount contributed by a given eddy at that 1/3-octave frequency. Theoretically, all eddies contribute some amount at all 1/3-octave frequencies, but the rather "peaky" nature of  $I(\Omega)$  given by equation (16) dictates that the major contribution of an eddy will be in the vicinity of  $\Omega \sim 4/\tau_0$ .

Computationally, the integrand of equation (14) can be expressed explicitly in terms of observed frequency, since the source frequency always occurs in the combination  $\Omega/(1-M_c \cos \theta)$ . The one exception is in the exponent of the spectrum function  $I(\Omega)$ , equation (16). For example, the product  $\alpha a_{xx}$  can be rewritten as

$$\alpha a_{xx} \sim \frac{\rho_a^2 (u')^7 (2\pi f \tau_0)^4 \beta_{xx} \cos^4 \theta (C_a/C_0)^2}{16\pi^2 R^2 C_a^4 (1-M_0 \cos \theta)^2 (1-M_c \cos \theta)^2} \exp \left[ -\frac{1}{8} (\Omega \tau_0)^2 \right]$$

Similar expressions can be derived for  $\alpha a_{xy}$ , etc.

The eddy convection factor  $(1-M_c \cos \theta)$  has a singularity at  $M_c \cos \theta = 1$ . To circumvent this computational difficulty, it is replaced by a modified convection factor as suggested by Ffowcs-Williams (6) and Ribner (8), as follows:

$$C = 1 - M_c \cos \theta + \sqrt{(1 - M_c \cos \theta)^2 + (\alpha_t u' / C_a)^2} \quad (27)$$

where, as Ffowcs-Williams and Ribner have shown, the term  $(\alpha_t u' / C_a)$  accounts for the finite life-time of the eddy as it is convected downstream. The constant  $\alpha_t$  was determined (from comparison of prediction with experiments) to be approximately 0.5, independent of source location, jet operating conditions and nozzle geometry. An additional assumption was made that the flow convection factor  $(1 - M_o \cos \theta)$  can be replaced by the modified eddy convection factor  $C$  given by equation (27).

The eddy convection Mach number must be a function of the local flow Mach number of the eddy-volume being considered. Several expressions for  $M_c$  were tried; the best results (over a wide range of nozzle operating conditions and geometries) were obtained with the following:

$$M_c = \frac{1}{2} (M_o + 0.65 M_j) \quad (28)$$

where  $M_j = U_j / C_a$ , the nozzle exit acoustic Mach number. Equation (28) represents a simple average of the classical assumption  $M_c = 0.65 M_j$  and the local Mach number  $M_o = M(r_o)$ . For suppressor nozzles, equation (28) works best if  $M_j$  is replaced by the postmerged potential core Mach number  $M_m = U_m / C_a$ . This can be evaluated from the results of the flow field calculation described in Section 3.2.

The acoustic theory summarized in Section 3.3 applies only for axisymmetric jets. For nonaxisymmetric nozzles (multilobe, chute, tube, etc.), an assumption is therefore made that a representative average radial profile at each axial station can be derived which, when inserted in the acoustic calculation, will adequately model the acoustic characteristics of the asymmetric jet. The mass-averaged values of  $U$  and  $\rho$  are calculated from the azimuthal average of the quantities  $\rho U^2$  and  $\rho UH$ . The resulting distributions of  $U(x, r)$  and  $\rho(x, r)$  are then employed in the acoustic calculation described in Section 3.3.

For axisymmetric jets, the empirical similarity relation  $[\tau_o \sim (\partial U / \partial r)^{-1}]$  derived by Davies et al. (13) can be used to calculate the local value of  $\tau_o$  from the radial velocity profiles  $U(r)$ . For a multichute or lobe nozzle, however, there are volume elements close to the nozzle exit plane which have negligible radial gradients  $\partial U / \partial r$  but large azimuthal gradients  $\partial U / \partial \phi$ . It is therefore assumed that  $\tau_o$  is a function of both  $\partial U / \partial r$  and  $\partial U / \partial \phi$ . From Reichardt's hypothesis (see Reference 3), the transverse shear stresses are related to  $\partial U / \partial r$  and  $\partial U / \partial \phi$  by the approximate formulae

$$\frac{\tau_r}{\rho} \approx \lambda \frac{\partial U^2}{\partial r} \quad \text{and} \quad \frac{\tau_\phi}{\rho} \approx \frac{\lambda}{r} \frac{\partial U^2}{\partial \phi}$$

where  $\lambda = C_m^2 x/2$ . Thus the transverse derivatives of  $U$  can be expressed in terms of  $\tau_r$  and  $\tau_\phi$  as follows:

$$\frac{\partial U}{\partial r} \approx \frac{(\tau_r/\rho)}{U C_m^2 x} \quad \text{and} \quad \frac{1}{r} \frac{\partial U}{\partial \phi} \approx \frac{(\tau_\phi/\rho)}{U C_m^2 x}$$

A new transverse derivative  $\partial U/\partial n$  is therefore defined in terms of the above  $r$  and  $\phi$  derivatives as follows,

$$\frac{\partial U}{\partial n} = \frac{1}{U C_m^2 x} \sqrt{\left(\frac{\tau_r}{\rho}\right)^2 + \mu_t \left(\frac{\tau_\phi}{\rho}\right)^2} \quad (29)$$

such that

$$\tau_o \sim \frac{\partial U}{\partial n}^{-1} \quad (30)$$

The parameter  $\mu_t$  is an empirical constant which must be evaluated from comparison with experiments.

For prediction of jet noise in flight, the mean square sound pressure level should be multiplied by the dynamic amplification factor  $(1 + M_a \cos \theta)^{-1}$ , where  $M_a = U_a/C_a$ . In addition, the convection and flow Mach numbers are replaced by  $(M_c - M_a)$  and  $(M_o - M_a)$ , respectively, where  $M_c$  and  $M_o$  are evaluated in a reference frame fixed to the nozzle.

Finally, in all predictions of 1/3-octave spectra, the atmospheric attenuation corrections given by Reference (15) are applied, using standard-day corrections (70% relative humidity and 59° F dry-bulb temperature) evaluated at the center frequency.

## 4.0 COMPUTER PROGRAM DESCRIPTION

### 4.1 INTRODUCTION

The central theme of this report has been the development of a general method for predicting the aeroacoustic characteristics of turbulent jets for a wide range of nozzle flow conditions and nozzle geometries. The preceding section describes the analytic, algebraic relationships which have been developed to represent the various physical aspects of the mathematical model. The purpose of this section is to describe the computational algorithms and associated computer program which provides the necessary link between the symbolic representation of the model and the actual numerical results of the prediction method.

The computer program is written in FORTRAN IV language. It has been run on both the GE/Honeywell 6080 and CDC 7600 computers, and can easily be modified for running on other systems. The program subdivides the jet plume utilizing a built-in grid system which requires minimal input for specification. This grid system can be superseded by the user through more complex input if desired. The nozzle geometry is input through discrete point coordinates for each nozzle element boundary, and up to 109 elements can be input for a given case. A maximum of 24 axial stations along the jet plume is permitted, and up to 200 radial points per axial station can be accommodated. These limits can be changed if so desired by modifying the appropriate DIMENSION and COMMON statements in the program logic.

The limiting assumptions made in developing the method have been discussed in Section 3.0, but it is appropriate to summarize them here to warn against indiscriminate violation of these limitations. They are as follows:

1. The exhaust nozzle elements should be co-planar, i.e., each tube or chute of a multielement configuration should exhaust at the same axial plane. However, nozzle element exit planes can be staggered, provided that the mixing layer of a given element does not impinge on the wall of another element.
2. The jet exhaust gases must all be of the same constituent, because the calculation cannot accommodate gas mixtures or species concentrations.
3. Within any nozzle element, the flow is assumed to be uniform at the exit plane.
4. The time-averaged static pressure is assumed to be constant and uniform throughout the jet flow field and surrounding ambient field.
5. The exhaust nozzle elements must discharge axially, radial mean flow and swirl are neglected in the model.

6. The effects of shock formations on mixing and turbulence levels are neglected.

These assumptions and limitations are those which pertain to the types of problems which can be analyzed. There are, of course, additional assumptions which went into the formulation of the model itself which may restrict the accuracy of the model, but not the type of problem which can be analyzed. The user is advised to consult Reference (3) for the details of the model formulation.

#### 4.2 PROGRAM NOMENCLATURE AND SYMBOL CONVENTION

The jet plume and nozzle geometry coordinates are computed in the MAIN routine. The jet plume is divided into KX axial slices, specified by KA ( $1 \leq KA \leq KX$ ). The FORTRAN symbol variables for the various coordinate parameters and indices are shown in Figure 6. Note that the radial subdivision, specified by index M ( $1 \leq M \leq NR$ ), proceeds in increments DSIG(KA), from SIG = RMIN(KA) to the maximum value set by NR. The value of NR is determined during the calculation from the location where the axial momentum flux is within a certain tolerance of being equal to the ambient level, i.e.,

$$|RU2 - RU2E(1)| \leq RU2M$$

where RU2M is a specified input tolerance. The maximum allowable value of NR can be specified by the input variable IQUIT. The program dimension sizes limit KX and IQUIT to the following maximum values:

$$KX \leq 24 \qquad \qquad \qquad IQUIT \leq 200$$

The nozzle geometry itself is input as a number (NEST) of boundary elements. Each element is specified by coordinate pairs RA(I,J) and DALP(I,J), where RA(I,J) denotes the radius and DALP(I,J) denotes the angular increment, as shown in Figure 6. The index I denotes the boundary contour point number, and the index J denotes the boundary number. The reference angular location for each boundary is given by ALPO(J). For each boundary, the exit-plane values of total pressure PT(J) and total temperature TT(J) are also specified. Boundary number one (J=1) is always considered to be the ambient field.

The far field acoustic calculations are performed on either a constant-radius arc or a sideline parallel to the jet axis, according to whether the input variable NUMANG is set equal to 1 or 2, respectively. For NUMANG = 1, the input DIST is the arc radius; for NUMANG = 2, DIST is the sideline distance. The acoustic arena geometry specification in terms of FORTRAN variables is shown in Figure 7. Note that a distinction is made between the source-to-observer distance RSTAR and the nozzle-to-observer distance RADIUS. The observer angle relative to the jet axis THETA is always in units of radians, while the observer angle relative to the inlet axis THETD is in units of degrees. The far-field sound pressure level SPL(I,J) is computed at

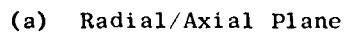
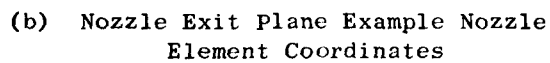


Figure 6. FORTRAN Symbol Convention for Coordinates and Geometric Variables.

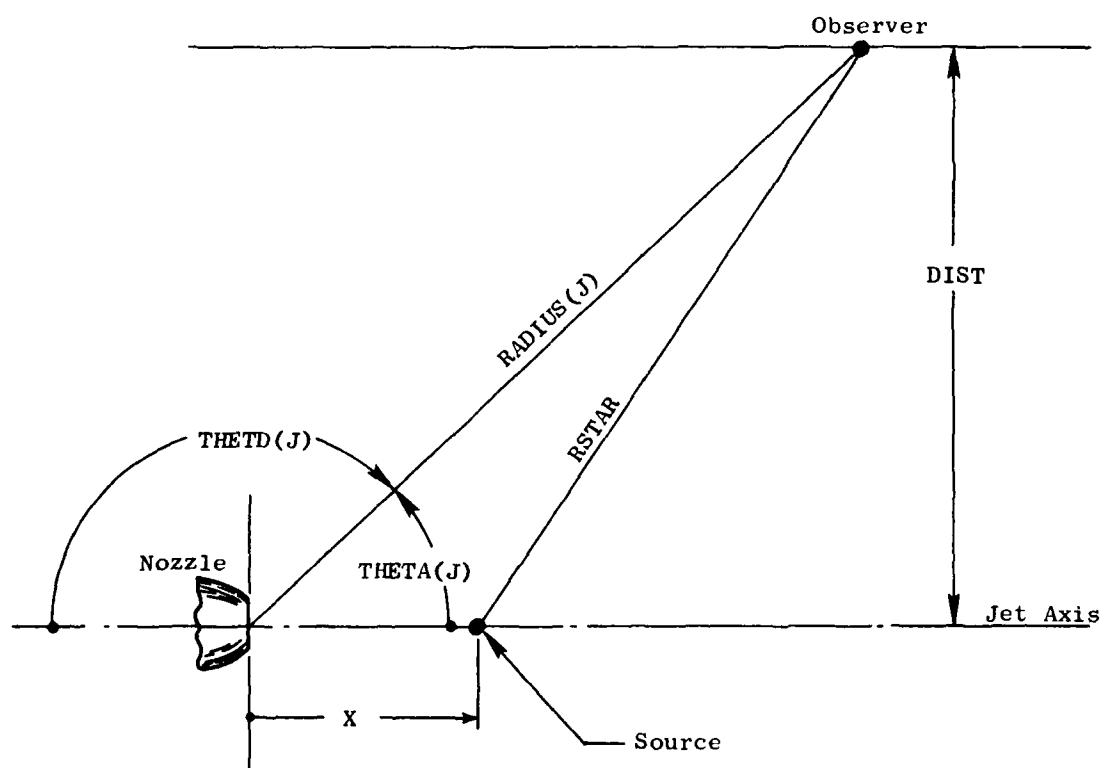


Figure 7. FORTRAN Symbol Convention for Acoustic Arena Variables.

every 1/3-octave frequency from FMIN to FMAX, at ten-degree increments from THETD = 20° to 160°.

A list of the important FORTRAN symbols used in the computer program is given in Table 2, along with their algebraic equivalents where possible. A complete description of all of the input variables and examples of input preparation are given in Appendix A.

#### 4.3 DESCRIPTION OF PROGRAM AND SUBROUTINES

A flow chart of the computer program logic is shown in Figure 8. It indicates the sequence of operations, the interconnections of various portions of the program, and their functions. A description of the main program and each of the subroutines is given in the following paragraphs.

##### 4.3.1 MAIN

The main program initiates the computation and controls the sequence of operations. It reads the input data, computes the grid system for the aerodynamic flow field, and computes the various required nozzle exit plane flow parameters such as velocities, Mach numbers, momentum and enthalpy fluxes, etc. The main program prints out all input data, nozzle exit conditions, nozzle geometry, and coordinate system parameters.

The main program controls and executes the jet plume flow field computation. After each axial slice has been evaluated, the MAIN program calls subroutine SLICE to perform the requested acoustic calculations. Upon completing the calculations at all axial slices, MAIN then calls OUTPUT to perform some final calculations and print out the far-field noise levels. If additional cases are requested, the entire procedure is repeated, beginning with reading of input data; otherwise the execution is halted.

##### 4.3.2 ARCCOS(X)

This is a function subroutine which computes the principal value of the arc cosine of the variable X. It is used in MAIN in evaluating certain angles relating boundary coordinate points and flow field location points.

##### 4.3.3 ERF(X)

This function subroutine evaluates the error function of argument X using polynomial approximations as given in Reference (19). It is used in MAIN for evaluating flow field integrands.



Table 2. List of FORTRAN Symbols.

FORTRAN Symbol	Meaning	Related Subroutines
AA	Air attenuation factor	ATMOS
AAA	Intermediate variable	LSPFIT, MAIN
ABDTH	$ \Delta\phi $	MAIN
ABLE	Intermediate variable	MAIN
ABPA	$ \phi-\alpha $	MAIN
ACH	Mach number M	MAIN
ACHM	Average mach number	MAIN
ACH2	$M^2$	MAIN
AK	Sound level constant	MAIN, OUTPUT
AL	Lighthill parameter	MAIN
ALFA	Frequency constant	MAIN
ALP	Angle	MAIN
ALPHT	Convection constant $\alpha_t$	SLICE
ALPØ	Reference boundary angle	MAIN
AMUIN	Input turbulence constant $\mu_t$	MAIN
AMULT	Intermediate value for $\mu_t$	MAIN
AO	Speed of sound $C_a$	MAIN
ATOTAL	Total flow area	MAIN
B	Intermediate variable	LSPFIT
BETA	Shock strength parameter $\beta$	SHOCK
BETAIN	Input turbulence constant $\beta_t$	MAIN
BETAMC	Convection constant $\beta_{Mc}$	MAIN, SLICE
BK	Intermediate variable	SLICE
BKR	Intermediate variable	MAIN
BOT	Intermediate variable	LSPFIT
BUG	Intermediate variable	MAIN
C	Constant	LSPFIT
CH	Spreading parameter $C_h/C_m$	MAIN
CHX	Spreading parameter $C_{hx}$	MAIN
CJOCO	Ratio of $C_j/C_a$	SLICE
CM	Spreading parameter $C_m$	MAIN
CMAX	Intermediate variable	TPNLC
CMC	Intermediate variable	MAIN
CMMC	Spreading constant $C_1$	MAIN
CMVR	Spreading constant $C_2$	MAIN
CNST	Constant	SLICE
CO	Ambient speed of sound $C_a$	MAIN, SLICE, SHOCK
COEF	Conversion factor	OUTPUT
CONV	Convection factor	SHOCK
CONVF	Flight dynamic factor	SLICE
CONVO	Convection factor	SLICE
CONV2	Modified convection factor C	SLICE
CON1	Constant	SLICE

Table 2. List of FORTRAN Symbols (Continued).

FORTRAN Symbol	Meaning	Related Subroutines
CON2	Constant	SLICE
COST	$\cos \phi$	MAIN
COSTO	$\cos \phi$	MAIN
CP	Specific heat $C_p$	MAIN
CT	$\cos \theta$	SLICE, CRD
CTSQ	$\cos^2 \theta$	SLICE
CTH	$\cos \theta$	SHOCK
CVR	Intermediate variable	MAIN
DALP	Boundary coordinate $\Delta\alpha$	MAIN
DDTHE	Tolerance on $\Delta\theta$ , radians	SLICE
DDTHED	Tolerance on $\Delta\theta$ , degrees	SLICE
DELRA	Transformed boundary radius $\Delta v$	MAIN
DELSIG	Transformed radius $\Delta r$	MAIN
DELTA	Turbulence constant $\delta_t$	MAIN
DELTIN	Input array of $\delta_t$	MAIN
DEQ	Equivalent diameter $D_{eq}$	MAIN, SLICE, SHOCK
DIA	Reference $D_{eq}$	MAIN
DIRECT	Directivity factor	SLICE
DIST	Sideline or arc distance	MAIN, SLICE
DJET	Reference diameter	MAIN
DPHI	$\Delta\phi$	MAIN
DRMIN	$\Delta r$ - minimum value	SLICE
DS	Source strength amplitude	SLICE
DSIG	$\Delta r$	MAIN, SLICE
DSPL	Mixing noise pressure	SLICE, OUTPUT
DSPL1	Intermediate variable	SHOCK
DSPL2	Intermediate variable	SHOCK
DTHED	$\Delta\theta$ , degrees	SLICE
DTHM	Maximum increment of $\phi$	MAIN
DU	Intermediate variable	MAIN
DUDR	$\partial U / \partial r$	MAIN, SLICE
DV	Eddy volume $dV$	SLICE
DX	Axial step size $\Delta x$	MAIN, SLICE
EF	Enthalpy flux	MAIN
EFE	Enthalpy flux	MAIN
EM	Mach number	SLICE
EMACH	Exit Mach number	MAIN, SLICE, OUTPUT
F	Intermediate variable	LSPFIT
FAC	Intermediate variable	PNLC
FC	Center frequency	SLICE
FIRSTU	Flight velocity $U_a$	MAIN, SLICE
FIS	Intermediate variable	MAIN
FM	Mass flow	MAIN

Table 2. List of FORTRAN Symbols (Continued).

FORTRAN Symbol	Meaning	Related Subroutines
FMAX	Maximum observed frequency	MAIN, OUTPUT
FMIN	Minimum observed frequency	MAIN, OUTPUT
FO	Observed frequency	SLICE, SHOCK, OUTPUT
FP	Peak frequency	SHOCK
FR	Frequency ratio	SLICE
FRSQ	Intermediate variable	SLICE
FS	Source frequency	SLICE
GAM	Specific heat ratio $\gamma$	MAIN, SHOCK
GAMA	Gas constant parameter	MAIN
GEXP	Gas constant parameter	SHOCK
GM	Shielding function	CRD
GOSQ	Shielding function	CRD
G2	Shielding function	SLICE, CRD
HF	Spectrum function	SLICE
HPSI	Intermediate variable	MAIN
HTR	Stagnation enthalpy	MAIN
I	Index	ALL
IC	Index	LSPFIT
IDENT	Title (80-characters)	MAIN
II	Index	TPNLC
IMH	Index	MAIN
IQUIT	Maximum number of points	MAIN
IS	Index	MAIN
ISSY	Index	MAIN
ISAVE	Index	LSPFIT
ISYM	Symmetry indicator	MAIN
IT	Symmetry indicator	MAIN
J	Index	ALL
JMAX	Maximum band number	OUTPUT, SHOCK, SLICE
JMIN	Minimum band number	OUTPUT, SHOCK, SLICE
J1	Index	CRD
J11	Index	CRD
J2	Index	CRD
J21	Index	CRD
J211	Index	CRD
K	Index, also wave number	MAIN, SLICE, PNL
KN	Surrounding boundary index	MAIN
KNCAS	Case counter	MAIN
KNK	Surrounding boundary index	MAIN
KX	Number of axial slices	MAIN
L	Index	MAIN
LAVG	Shock spacing	SHOCK
LEAF	Number of boundary leaves	MAIN

Table 2. List of FORTRAN Symbols (Continued).

FORTRAN Symbol	Meaning	Related Subroutines
LEAV	Number of boundary leaves	MAIN
LINE	Printout counter	MAIN
LPHI	Number of flow field leaves	MAIN
LQ	Index	MAIN
M	Index	MAIN, SLICE
MACH	Mach number	SLICE
MAXNOY	Maximum noy value	PNLC
MC	Convection Mach number	SLICE, SHOCK, CRD
MCIN	Input array of $M_c$	SLICE
MIN	Input array of $M_o$	CRD
MJ	Jet exit Mach number	SHOCK
N	Index, also number of shocks	MAIN, SHOCK, LSPFIT
NBREF	Reference boundary number	MAIN
NCASE	Number of cases	MAIN
NCBDY	Number of centerbody points	MAIN
NCELL	Number of shock cells	MAIN, SHOCK
NCOUNT	Counter	LSPFIT
NN	Acoustic calculation selector	MAIN, SLICE
NODE	Intermediate variable	MAIN
NOV	Minimum number of points	MAIN
NOY	Noy value	PNLC
NPAGE	Page counter	MAIN
NPR	Printout counter	MAIN
NPRINT	Printout selector	MAIN, SLICE
NPTS	Number of points	LSPFIT
NR	Number of points	SLICE, CRD
NRI	Index	SLICE
NTP	Number of turning points	SLICE, CRD
NUM	Number of boundary points	MAIN
NUMANG	Arena selector	MAIN, SLICE
NUMK	Number of boundary points	MAIN
NXC	Index	LSPFIT
OAPWL	Overall power level	OUTPUT
OASPL	Overall sound pressure level	OUTPUT, PNLC
OBSTN	Observed Strouhal number	OUTPUT
OMEGR	Source radian frequency	SLICE
PAA	Ambient static pressure	MAIN
PC	Intermediate variable	PNLC
PGC	Gas constant parameter	MAIN
PHI	Angle $\phi$	MAIN
PI	Constant $\pi$	MAIN, SLICE, OUTPUT
PI02	$\pi/2$	CRD
PI2	$2\pi$	MAIN

Table 2. List of FORTRAN Symbols (Continued).

FORTRAN Symbol	Meaning	Related Subroutines
PNDDB	PNdB	PNLC
PNL	PNL	OUTPUT, PNLC
PNLT	PNL <sub>t</sub> , tone-corrected PNL	OUTPUT
POWER	Exponent	MAIN
PS	Ambient static pressure	MAIN, SHOCK
PSQ	Square of acoustic pressure	OUTPUT
PSQM	Mixing noise $\overline{p^2}$	SHOCK
PSQS	Shock noise $\overline{p^2}$	SHOCK
PSQT	Total noise $\overline{p^2}$	SHOCK
PT	Stagnation pressure	MAIN, SHOCK
PWL	Power level	OUTPUT
PWR	Sound power, watts	OUTPUT
Q	Intermediate variable	MAIN
RA	Boundary coordinate radius	MAIN
RAD	Flow integration variable $R_0$	MAIN
RADO	Flow integration variable $R_0$	MAIN
RADIUS	Nozzle-to-observer radius $R$	SLICE, OUTPUT, ATMOS
RADX	Argument $R_0/C_m x$	MAIN
RCBDY	Centerbody radial coordinate	MAIN
PRCRIT	Critical pressure ratio	SHOCK
RCRC	Intermediate variable	MAIN
RFO	Intermediate variable	OUTPUT
RHO	Density $\rho$	MAIN
RHOE	Ambient density $\rho_a$	MAIN, SLICE
RHOESQ	$\rho_a^2$	SLICE
RHOR	Azimuthally-averaged $\rho$	MAIN, SLICE
RIN	Input radius	SLICE, CRD
RJET	Reference jet density ratio	MAIN
RMIN	Minimum value of $r$	MAIN
RMINEX	Exit plane value of $R_{MIN}$	MAIN
RMINSQ	Square of $R_{MIN}$	MAIN
RMNSQE	Square of $R_{MINEX}$	MAIN
RMP	Dummy variable	MAIN
RND	Normalized radius $r/D_{eq}$	MAIN
ROOT	Root (zero) of $g^2$	SLICE
ROOT2	$\sqrt{2}$	SLICE
RO	Source radius $r_0$	CRD
RSIG	Turning point radius $r_0$	SLICE, CRD
RSIG1	$r_{01}$	CRD
RSIG2	$r_{02}$	CRD
RSORSQ	Source location correction $(R^*/R)^2$	SLICE
RSTAR	Source-to-observer radius $R^*$	SLICE

Table 2. List of FORTRAN Symbols (Continued).

FORTRAN Symbol	Meaning	Related Subroutines
RU	Mass flux $\rho U$	MAIN
RU2	Momentum flux $\rho U^2$	MAIN
RU2E	Exit plane value of $\rho U^2$	MAIN
RU2M	Minimum value of $\rho U^2$	MAIN
RU2REF	Reference value of $\rho U^2$	MAIN
R1	Intermediate variable	CRD
R2	Intermediate variable	CRD
S	Intermediate variable	TPNLC
SA	Intermediate variable	MAIN
SAC	Intermediate value of $\tau_\phi$	MAIN
SACO	Intermediate value of $\tau_\phi$	MAIN
SAR	Intermediate value of $\tau_r$	MAIN
SARO	Intermediate value of $\tau_r$	MAIN
SAX	Intermediate value of $\tau_x$	MAIN
SAXO	Intermediate value of $\tau_x$	MAIN
SBAR	Intermediate variable	TPNLC
SDU	Intermediate value of $\partial U / \partial r$	MAIN
SEFE	Integral of enthalpy flux	MAIN
SGN	Sign	LSPFIT
SGN1	Sign	CRD
SGN2	Sign	CRD
SG1	Intermediate variable	CRD
SG2	Intermediate variable	CRD
SHIELD	Shielding integral	SLICE, CRD
SIC	Intermediate value of $\tau_\phi$	MAIN
SIG	Radius $r$	MAIN
SIGN	Sign	ERF
SIGSQ	$r^2$	MAIN
SIGR	Radius $r$	MAIN, SLICE
SINT	Sin $\theta$	MAIN
SINTO	Sin $\theta_0$	MAIN
SIR	Intermediate value of $\tau_r$	MAIN
SIX	Intermediate value of $\tau_x$	MAIN
SPL	SPL array	ALL
SPLL	Intermediate variable	TPNLC
SPLMAX	Maximum SPL	SHOCK
SPLP	Intermediate variable	TPNLC
SPLPP	Intermediate variable	TPNLC
SPLU	Intermediate variable	TPNLC
SRU	Mass flux integral	MAIN
SRUM	Mass flux integral	MAIN
SRU2	Momentum flux integral	MAIN
SRU2M	Momentum flux integral	MAIN

Table 2. List of FORTRAN Symbols (Continued).

FORTRAN Symbol	Meaning	Related Subroutines
SS	SPL array	PNLC
SSPL	Shock noise SPL array	SHOCK
STC	Azimuthal shear stress $\tau_\phi$	MAIN
STR	Radial shear stress $\tau_r$	MAIN
STRFR	Radial coordinate stretching factor	MAIN
STRFX	Axial coordinate stretching factor	MAIN
STX	Axial shear stress $\tau_x$	MAIN
SUE	Reference velocity	MAIN
SUM	Sum	OUTPUT
SUMNOY	Sum of noy value	PNLC
SUMSPL	Sum of SPL	PNLC
SUM1	Sum	CRD
SUM2	Sum	CRD
SU8	Integral of source strength	MAIN
SU8M	Integral of source strength	MAIN
SV2	Square of velocity	MAIN
S1	Intermediate variable	LSPFIT
T	Temperature	ERF, MAIN
TA	Intermediate variable	MAIN
TAA	Ambient static temperature	MAIN
TAO	Intermediate variable	MAIN
TAU	Total shear stress $\tau$	MAIN
TAUR	Azimuthal average of $\tau$	MAIN, SLICE
TC2	Intermediate variable	TPNLC
TC3	Intermediate variable	TPNLC
TE	Exit static temperature	MAIN
TEMP	Normalized temperature $T/T_a$	SLICE
TERM	Directivity factor	SLICE
TH	Angle $\phi$	MAIN
THCR	Critical angle $\theta_{cr}$	SHOCK
TERM	Directivity factor	SLICE
THE	Angle $\theta$	SLICE, CRD
THETA	Observer angle $\theta$ , radians	SLICE, OUTPUT
THETD	Observer angle $\theta_I$ , degrees	SLICE, OUTPUT, SHOCK
THO	$\phi_0$	MAIN
THT	Observer angle $\theta_I$ , radians	SHOCK
TI	Intermediate value of enthalpy flux	MAIN
TOP	Intermediate variable	LSPFIT
TSR	Static temperature	MAIN
TSTD	Circumferential asymmetry test parameter	MAIN
TSTH	Circumferential asymmetry test parameter	MAIN
TSTHL	Circumferential asymmetry test parameter	MAIN
TSTL	Circumferential asymmetry test parameter	MAIN

Table 2. List of FORTRAN Symbols (Concluded).

FORTRAN Symbol	Meaning	Related Subroutines
TT	Stagnation temperature	MAIN
TTR	Stagnation temperature	MAIN
TURBIN	Turbulence intensity, $u'$	MAIN
U	Mean velocity	MAIN
UAP	Intermediate variable	MAIN
UAVG	Mass-average of U at x	MAIN
UC	Convection velocity $U_c$	SHOCK
UE	Exit plane velocity $U_j$	MAIN, SHOCK
UGLY	Intermediate variable	MAIN
UJET	Reference exit velocity	MAIN
UMAX	Maximum local value of U at x	MAIN
UND	Normalized value of U, $U/UREF$	MAIN
UNITS	Constant for units conversion	MAIN, OUTPUT
UR	Azimuthal average of U	MAIN, SLICE
UREF	Reference exit velocity	MAIN
U8	Intermediate value of source strength	MAIN
U8I	Integral of source strength	MAIN
VA	Intermediate value of momentum	MAIN
VAO	Intermediate value of momentum	MAIN
VI	Intermediate value of momentum	MAIN
VMAX	Maximum of velocities inside and outside	MAIN
VMIN	Minimum of velocities inside and outside	MAIN
VO	Flight velocity $U_a$	SHOCK
VR	Velocity ratio $V_{MIN}/V_{MAX}$	MAIN
WITHIN	Dummy variable	LSPFIT
X	Axial distance x	MAIN, SLICE
XCBDY	Centerbody axial coordinate	MAIN
XD	Intermediate variable	LSPFIT
XE	Exit plane axial coordinate	MAIN
XND	Normalized axial coordinate $X/D_{eq}$	MAIN
XOR	Variable $x/R$	SLICE
X1	Intermediate variable for curve fitting	LSPFIT
X13	Intermediate variable for curve fitting	LSPFIT
X4	Intermediate variable for curve fitting	LSPFIT
X43	Intermediate variable for curve fitting	LSPFIT
Y	Intermediate variable for curve fitting	LSPFIT
YC	Intermediate variable for curve fitting	LSPFIT
YI	Intermediate variable for curve fitting	LSPFIT
Y3	Intermediate variable for curve fitting	LSPFIT



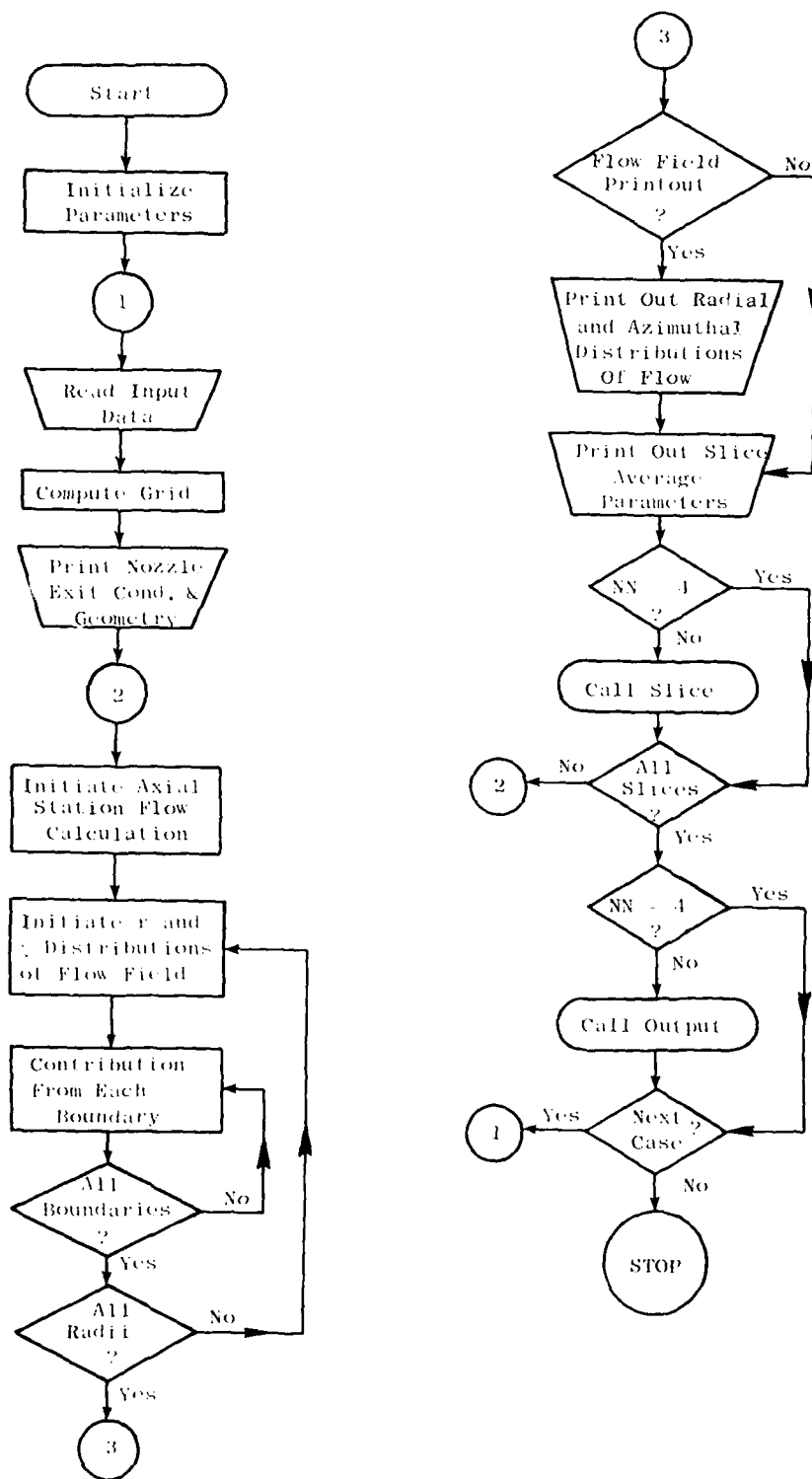
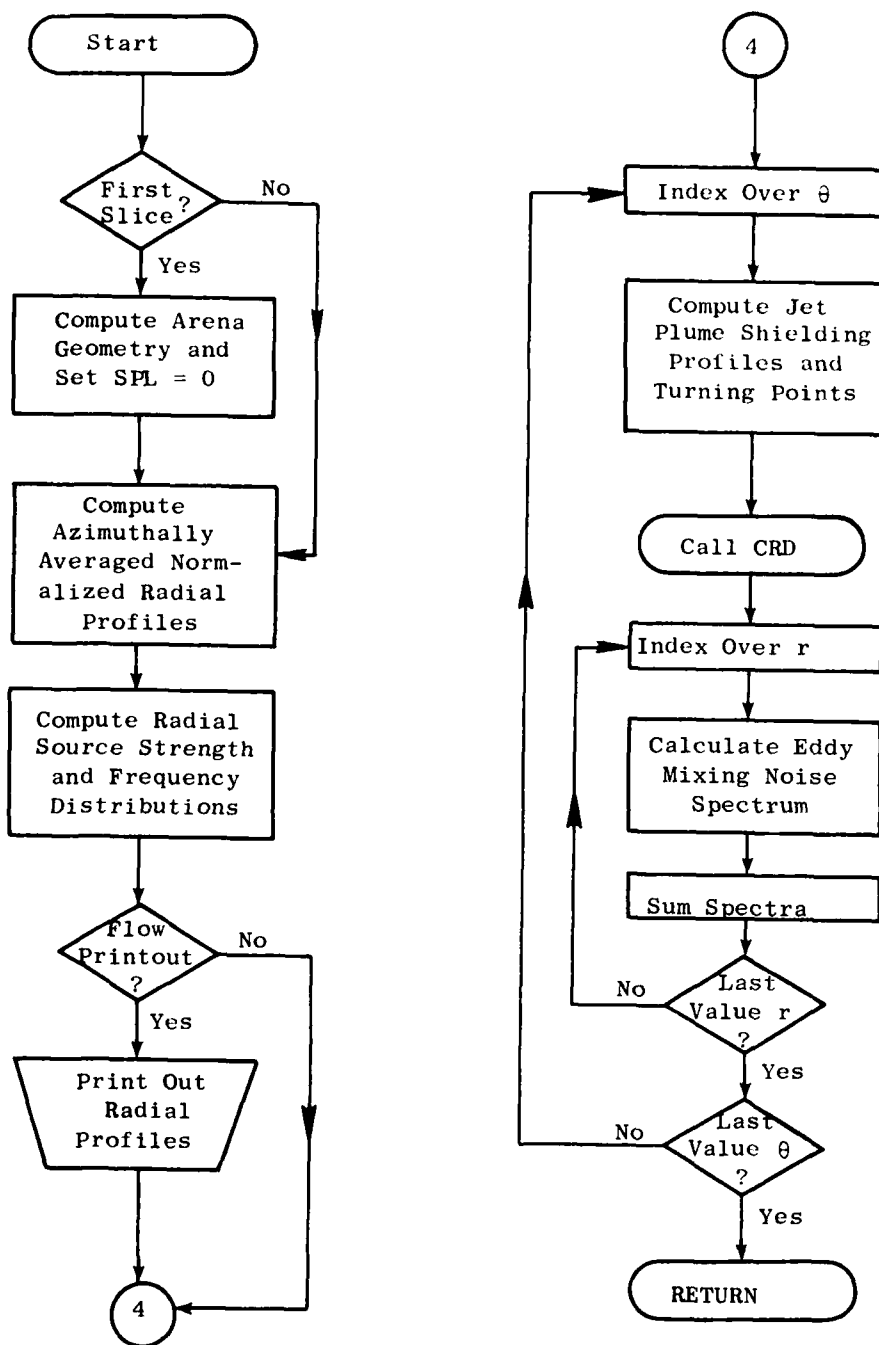
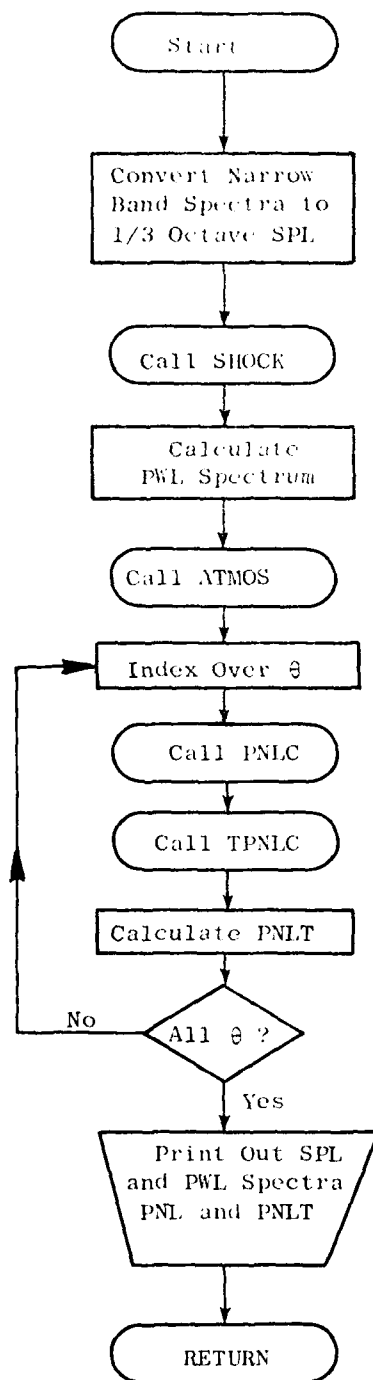


Figure 8. Computer Program Flow Chart.



(b) Subroutine SLICE

Figure 8. Computer Program Flowchart (Continued).



(c) Subroutine OUTPUT

Figure 8. Computer Program Flow Chart (Concluded).

#### 4.3.4 LSPFIT

Subroutine LSPFIT is a curve-fitting routine which utilizes least-squares polynomial fits of second order to perform interpolation, differentiation and integration of input discrete-point data. The calling statement is:

```
CALL LSPFIT(X, Y, N, XC, YC, NC, NF, A)
```

where (X, Y) are the input data coordinates (N values of each), XC are the values of X where output is requested, YC are the output functions, NC is the number of output data points, and NF indicates the type of output desired. The coding for NF is as follows:

NF = 0, YC are interpolated values of Y

NF = 1, YC are derivatives of Y

NF = -1, YC is the integral of Y from  
XC(1) to XC(J),  $1 \leq J \leq NC$ .

The parameter A is the second derivative of Y. Subroutine LSPFIT is used in MAIN to interpolate input plug/centerbody geometry coordinates at various axial stations in the flow field, and to obtain radial gradients of density from the computed density profiles.

#### 4.3.5 SLICE

Subroutine SLICE directs the mixing noise calculation for each axial slice. The calling sequence is as follows:

```
CALL SLICE (X(KA), DSIG(KA), DX, M)
```

where X(KA) is the axial location, DSIG(KA) is the radial step size, DX is the axial slice thickness, and M is the number of radial points in the slice. The flow parameters (which are circumferentially mass-averaged values) are transferred through labeled COMMON statements. Subroutine SLICE computes the acoustic arena geometry parameters THETA, THETD, RADIUS and initializes SPL (I,J) to zero during the first call, skipping this calculation on succeeding calls. The normalized radial profiles of velocity (MACH) and temperature (TEMP) are evaluated, followed by a calculation of source strength amplitude DS and characteristic frequency FS for each radial volume element.

Subroutine SLICE computes the acoustic shielding function profiles  $G_2(J)$ , the number of turning points NTP, and their locations RSIG. Subroutine CRD is then called to calculate the acoustic shielding exponentials and quadrupole directivity functions. Subroutine SLICE then sums up the mixing noise contributions from each radial volume element, factoring in their individual source strengths, characteristic frequencies, spectrum shapes, directivities, and shielding factors. The resulting noise spectra from each slice is stored as the variable DSPL(I,J), where I denotes the observer angle index and J is the 1/3-octave frequency band index. Upon completing the calculation for a given slice, SLICE returns control to MAIN.

#### 4.3.6 CRD

Subroutine CRD computes the shielding function integrals and quadrupole directivity factors for a given axial slice as a function of radial source location. The radial distributions of normalized velocity (MACH) and temperatures (TEMP) and shielding function ( $G_2$ ) are transferred to CRD through labeled COMMON statements. The calling statement is:

CALL CRD

At each source radius, subroutine CRD interrogates the data to determine which of the six shielding conditions in Figure 4 applies, and computes the appropriate shielding integral ( $\beta_{01}$ ,  $\beta_{02}$ , or  $\beta_{12}$ ), and the appropriate directivity factors. After all radial source volumes have been evaluated, CRD returns control to SLICE.

#### 4.3.7 OUTPUT

Subroutine OUTPUT performs the final acoustic calculations and prints out the far field SPL spectra, OASPL, PNL and PNLT directivities. The calling sequence is as follows:

CALL OUTPUT (EMACH, DJET, RJET, UJET, UNITS)

where EMACH, DJET, RJET, and UJET are the characteristic (usually reference) jet Mach number, diameter, density ratio and velocity, respectively. The parameter UNITS is a conversion factor for converting from  $\text{lb}_f/\text{ft}^2$  to  $\text{dynes}/\text{cm}^2$  relative to  $0.0002 \text{ dynes}/\text{cm}^2$ . Subroutine OUTPUT converts the narrow-band spectra from SLICE into 1/3-octave levels. Subroutine SLICE then calls SHOCK to compute SSPL spectra (shock noise) and adds these to the turbulent mixing noise spectra to obtain the total noise spectra. The corresponding power spectrum (PWL) is then computed, and subroutine ATMOS is then called to correct all SPL spectra for atmospheric attenuation. Subroutines PNLC and TPNLC are then called to calculate perceived noise level

PNL and tone-corrected noise level PNLT. Finally, overall sound pressure level OASPL is computed, and all of these acoustic parameters are then printed out. Subroutine OUTPUT then returns control to MAIN.

#### 4.3.8 SHOCK

Subroutine SHOCK computes the broadband shock-associated noise spectra at each observer angle. The calling statement is as follows:

CALL SHOCK

All parameters are transferred into and out of this subroutine through labeled COMMON statements. Subroutine SHOCK computes the 1/3-octave SPL spectra for each nozzle boundary element which has a non-zero shock cell number input, NCELL > 0. The individual boundary contributions are summed on a mean-square pressure basis and added to the mixing noise spectra.

#### 4.3.9 ATMOS

Subroutine ATMOS corrects the input SPL spectra for atmospheric attenuation effects using standard-day atmospheric absorption factors for 70% relative humidity and 59° F ambient conditions. The calling sequence is as follows:

CALL ATMOS (SPL, RADIUS)

where SPL(I,J) is the sound pressure spectrum array, I denotes the index for observer angle, J denotes the index on frequency, and RADIUS(I) is the nozzle-to-observer distance array. The atmospheric absorption in dB per 1000 ft from reference (15) is corrected to the proper distance RADIUS(J), and the result is subtracted from SPL(I,J). The array of SPL(I,J) returned to OUTPUT is the corrected array.

#### 4.3.10 PNLC

Subroutine PNLC computes the perceived noise level in PNdB at each observer angle from the input 1/3-octave spectra. The calling sequence is as follows:

CALL PNLC (SS, FAC, PNDB, OASPL)

where SS is the input array of either 1/3-octave or octave SPL values, FAC is a constant equal to 0.15 for 1/3-octave and 0.3 for octave levels, PNDB is the output PNL, and OASPL is the conventional overall level. The method used to calculate PNL is taken from reference (17). The OASPL output from subroutine PNL is discarded because it only computes the summation for the first 24 values of SS. This is sometimes insufficient for model scale conditions where the frequency range of interest can cover as many as 33 1/3-octave frequency bands.

#### 4.3.11 TPNLC

Subroutine TPNLC determines a pure-tone correction factor to the PNL value as a function of the 1/3-octave SPL spectrum. The calling sequence is as follows:

CALL TPNLC (SPL, PTCOR)

where SPL is the input 1/3-octave spectrum and PTCOR is the correction to be applied to PNL to account for the presence of tones in the spectrum. Subroutine TPNLC reads in SPL and returns PTCOR. The tone correction and detection procedure is based on the method proposed in reference (18).

#### 4.4 PROGRAM USAGE AND LOGIC

A complete description of the program input variables and input format is given in Appendix A. A list of notes and suggestions on running the program is also included. A description of program output format, including warning flags and diagnostics, is given in Appendix B. A sample case listing (including input data card images) is given in Appendix C for a 7-tube suppressor nozzle, one of the data-theory comparison cases presented in Reference (3). A complete FORTRAN source listing of the program logic is given in Appendix D.

Program users should be completely familiar with Appendix A, since there are many pitfalls which can be avoided by giving attention to the recommendations presented therein. The program flexibility permits analysis of nozzle planforms of any imaginable shape, so long as certain input rules and guidelines are followed. When non-axisymmetric nozzles are run, a completely three-dimensional, turbulent, compressible flow field analysis is performed, and input mistakes can be costly in terms of computer processor time. The user should make initial checkout runs for complex nozzles, running just one or two axial slices at first, to ensure that all input is as desired, before running a complete jet plume.

The program is designed to serve as a diagnostic tool, in addition to functioning in the standard jet noise prediction mode. Individual slice calculations can be made by suitable input selection, running each slice (or

...finite case. This mode permits evaluation of the  
...each slice at each frequency and observer angle.  
...acoustic model can be bypassed to assess, for  
...effects of convection, acoustic shielding, etc. The  
...used to predict only the jet flow field, if desired.



## 5.0 CONCLUDING REMARKS

A theoretical analysis and associated computer model for the solution of the flow field and the acoustic characteristics of nozzles of arbitrary geometry is presented. A large number of cases have been calculated with this model and compared with appropriate experimental data (Reference 3). The computerized procedure presented herein provides a reasonably accurate method of predicting the aeroacoustic characteristics of a wide variety of exhaust nozzles over the range of flow conditions of interest, at least for those conditions and or observer angles where shock-cell noise does not dominate the spectrum.

## APPENDIX A

### DESCRIPTION OF INPUT

The input data is supplied through NAMELIST input format, with the exception of the alphanumeric title data card, which precedes the input NAMELIST data. Any number of successive cases can be run consecutively, limited only by the user's execution time available. Each successive case requires a title card (80 - character label in columns 1 - 80), followed by the INPUT NAMELIST. The data from preceding cases remains in storage, so only those variables which are to be changed from the preceding case input value need be included in the INPUT file of succeeding cases.

A suggested input preparation format is given in Table A-1. Those variables marked by an asterisk (\*) have preset values built into the program, and need not be input unless the user desires to over-ride the preset value with a different one. The definitions of each of the input variables given in Table A-1 are listed in Table A-2. Again, preset variables are marked by an asterisk (\*). The values of those variables which are preset are given in Table A-3. The format of Table A-2 is such that a note number (where appropriate) is given for each variable which corresponds to the note number in Section A.1 (Notes on Input). These notes give further elaboration on how to specify and prepare the input data.

Table A-1. Suggested Input Format.

Column  
2

(80 - CHARACTER TITLE CARD, COLUMNS 1-80)

\$INPUT

KX\* = \_\_\_\_\_, NEST = \_\_\_\_\_, LPHI\* = \_\_\_\_\_, ISYM = \_\_\_\_\_,  
 IQUIT\* = \_\_\_\_\_, NN\* = \_\_\_\_\_, NCASE\* = \_\_\_\_\_, NBREF\* = \_\_\_\_\_,  
 NPRINT\* = \_\_\_\_\_, NCBDY = \_\_\_\_\_,

NØV = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 X = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 DSIG = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 BETAIN\* = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 DELTIN\* = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 AMUIN\* = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 RMIN = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,

XE = 0 \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 ALPØ = 0 \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 LEAV = 1 \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 NUM = 1 \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 KN = 1 \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 DEQ = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 DS = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 NCELL = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,

PT = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 TT = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,

Table A-1. Suggested Input Format (Concluded).

Column  
2

DALP(1,2) = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 DALP(1,3) = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 (etc., for boundary 4, 5, 6, .....NEST)  
 RA(1, 2) = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 RA(1, 3) = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 (etc., for boundary 4, 5, 6, .....Nest)  
 CM\* = \_\_\_\_\_, CH\* = \_\_\_\_\_, CMVR\* = \_\_\_\_\_, CMMC\* = \_\_\_\_\_,  
 GAM = \_\_\_\_\_, CP = \_\_\_\_\_, PS = \_\_\_\_\_, ALFA\* = \_\_\_\_\_,  
 DTHM\* = \_\_\_\_\_, RU2M\* = \_\_\_\_\_, AK\* = \_\_\_\_\_, BK\* = \_\_\_\_\_,  
 STRFR\* = \_\_\_\_\_, STRFX\* = \_\_\_\_\_, ATOTAL = \_\_\_\_\_,  
 ALPHMC\* = \_\_\_\_\_, BETAMC\* = \_\_\_\_\_,  
 NUMANG = \_\_\_\_\_, DIST = \_\_\_\_\_, FMIN\* = \_\_\_\_\_, FMAX\* = \_\_\_\_\_,  
 ALPHT\* = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 XCBY = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 RCBY = \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_,  
 \$

(NEXT CASE, IF ANY)

Table A-2. Input Variable Definitions.

Variable	Note	Description
KX*		Number of axial stations to be analyzed; a maximum of 24 stations is permitted.
NEST	1	Number of closed boundary contours defining the nozzle exit geometry. A maximum of 110 is permitted.
LPHI	7	Number of symmetric leaves (repeating segments in the nozzle exit planform.
ISYM		Nozzle symmetry indicator; ISYM = 1 for axisymmetric nozzles or completely asymmetric nozzles, = 0 otherwise.
IQUIT		Maximum number of radii at which flow field is calculated ( $\leq 200$ ).
NN*	12	Acoustic Calculation option indicator.
NCASE*		Number of cases to be run consecutively.
NBREF*		Reference condition boundary number.
NPRINT*	13	Aerodynamic station printout indicator.
NCBDY	9	Number of centerbody input coordinate points. A maximum of 40 is permitted.
NØV		Minimum number of radii at which flow field is to be calculated, for each axial station (KX values required).
X	11	Axial location of each axial station, ft. (KX values required).
DSIG	11	Radial step size to be taken for flow field calculation at each axial station, ft. (KX values required).
BETAİN*	15	Axial shear stress turbulence constant (KX values required).
DELTİN*		Azimuthal shear stress turbulence constant (KX values required).

Table A-2. Input Variable Definitions. (Continued)

Variable	Note	Description
AMUIN*		Azimuthal velocity gradient turbulence frequency constant (KX values required).
RMIN	9	Minimum radius for flow field calculation at each axial station (KC values required).
XE	8	Axial location of exit plane of each boundary, ft. (NEST values required).
ALPØ	2	Reference angle $\alpha_0$ from which the coordinates of each boundary point are specified, radians (NEST values required).
LEAV	1,4	Number of symmetric leaves (repeating segments) of each boundary (NEST values required).
NUM	1,5	Number of input points (coordinate pairs) to be supplied for each boundary (NEST values required).
KN	1	The number of the boundary which encloses a given boundary (NEST values required).
DEQ	16	Equivalent flow area diameter of each boundary, ft. (NEST values required).
DS	16	Shock-cell spacing characteristic dimension, usually hydraulic diameter, of each boundary, ft. (NEST values required).
NCELL	16	Number of shock cells for each boundary element (NEST values required).
PT	6	Stagnation pressure inside each boundary, $\text{lb}_f/\text{ft}^2$ (NEST values required).
TT	6	Stagnation Temperature inside each boundary °R (NEST values required).
DALP(I,J)	2,3,5	Angular increment $\Delta\alpha$ from preceding boundary point which locates the given boundary point I on boundary J, radians (omit boundary number 1, ambient field).

Table A-2. Input Variable Definitions (Continued).

Variable	Note	Description
RA (I,J)	2,3,5	Radial coordinates of boundary point I on boundary J, ft. (omit boundary number 1, ambient field).
CM*	10	Empirical jet momentum diffusion rate spreading parameter $C_m$ .
CH*	10	Ratio of enthalpy-to-momentum spreading parameters $C_h/C_m$ .
CMVR*	10	Momentum spreading parameter velocity ratio influence coefficient.
CMMC*	10	Momentum spreading parameter Mach number influence coefficient.
GAM		Specific heat ratio $\gamma = C_p/C_v$ .
CP		Specific heat at constant pressure $C_p$ , in (ft-lbf)/(slug - °R).
PS		Ambient static pressure, lbf/ft <sup>2</sup> .
ALFA*		Turbulence characteristic frequency constant.
DTHM*	7	Maximum allowable increment in angular coordinate, $(d\phi)_{max}$ , for flow field calculation.
RU2M*		Minimum value of jet momentum flux, $(\rho U^2)_{min}$ , below which the flow is not calculated.
AK*		Sound pressure level proportionality constant for mixing noise calculation.
BK*		Sound pressure level proportionality constant for dipole density-gradient noise calculation.
STRFR*	11	Radial coordinate stretching factor for use of automatic mesh calculation.
STRFX*	11	Axial coordinate stretching factor for use of automatic mesh calculation.

Table A-2. Input Variable Definitions (Concluded).

Variable	Note	Description
ATOTAL		Nozzle Total exit flow area, $\text{ft}^2$ .
ALPHMC *	14	Convection Mach number weighting factor.
BETAMC *	14	Convection Mach number weighting factor.
NUMANG		Arena selection indicator; NUMANG = 1 indicates constant radius arc, NUMANG = 2 indicates sideline parallel to the jet axis.
DIST		Arc or sideline distance, ft.
FMIN *		Minimum frequency for which acoustic calculations are required, Hz ( $\geq 50$ ); an integer variable.
FMAX *		Maximum frequency for which acoustic calculations are required, Hz ( $\leq 100,000$ ); an integer variable.
ALPHT *		Convective amplification factor turbulence constant $\alpha_t$ ; 15 values required, one for each observer angle $\theta_I$ from $\theta_I = 20^\circ$ to $160^\circ$ in $10^\circ$ increments.
XCBDY	9	Centerbody input point axial coordinate, NCBDY values required.
RCBDY	9	Centerbody input point radial coordinate, NCBDT values required.



Table A-3. Preset Input Values.

<u>Variable</u>	<u>Value</u>
AK	0.08
ALFA	1.0
ALPHT	15* 0.5
ALPHMC	0.5
AMUIN	24* 0.2
BETAIN	24* 4.0
BETAMC	0.325
BK	0.0
CH	1.15
CM	0.075
CMMC	0.08
CMVR	0.25
DELTIN	24* 4.0
DTHM	0.1
FMAX	100000
FMIN	50
IQUIT	50
KX	15
LPHI	9999
NBREF	2
NCASE	1
NN	0
NPRINT	1
RU2M	3.0
STRFR	0.01
STRFX	1.259921

## A.1 NOTES ON INPUT

1. The jet nozzle geometry is specified by input of the number of component boundaries, NEST, along with pairs of coordinates, RA and DALP, for each boundary element. The ambient field is always treated as the first boundary in the input arrays for UE, PT, TT, LEAV, NUM, KN, XE, and ALPO. This is why some numbers have already been filled in on Table A-1 in the first column for these arrays. A nozzle with N elements has  $NEST = N + 1$  boundaries.
2. The steps to specifying nozzle geometry input are as follows, referring to Figure 6:
  - a. Obtain sketch or drawing of nozzle exit cross section and select a coordinate origin which is optimum from the standpoint of symmetry and boundary point specification.
  - b. Number each boundary, reserving boundary Number 1 for the ambient field.
  - c. With respect to the coordinate origin, select a reference angular location for each boundary,  $ALP\emptyset$ .
  - d. For each boundary, select points represented by pairs of coordinates. The coordinates used as input are radius,  $RA(I,J)$ , and angular increment from the preceding point,  $DALP(I,J)$ . For the first point,  $DALP(I,J)$  is the angular increment from the reference angle  $ALP\emptyset$ . The index I is the boundary point number, and the index J is the boundary number. Both  $ALP\emptyset$  and DALP are to be input in radians, and RA is input in feet.
3. The last point on a given boundary should be located at  $ALP\emptyset$  if the boundary has only one leaf. The sum of all  $DALP(I,J)$  should equal zero if the boundary has only one leaf.
4. If the boundary is a circle about the origin, only one point on the boundary need be supplied, and the value of LEAV for that boundary is set equal to the number of boundary points desired on the circle.
5. The program uses linear interpolation between input boundary points. If a boundary is made up of or contains straight line segments, only the end-points of the straight line segments need be input.
6. The variables PT and TT refer to stagnation pressure and temperature at the exit plane inside the boundary of interest. Setting the first value of PT equal to PS gives a static ambient field. The first value of PT greater than PS simulates non-zero flight velocity.

7. The variable LPHI determines what angular extent of the flow field needs to be calculated. If the nozzle geometry is axisymmetric, setting LPHI equal to a large number (such that  $2\pi/\text{LPHI}$  is less than DTHM) forces the program to calculate the flow field at only one angular location. The flow field for a nozzle containing two adjacent circular jets, for example, has  $\text{LPHI} = 4$ , since the flow is the same each quadrant. Several examples of how boundary parameters are specified are shown in Figure A-1.
8. The program can currently only handle coplanar nozzles, i.e., every nozzle element must terminate at the same axial location. Therefore XE must be the same for all input boundaries.
9. The centerbody, if any, is input through coordinates pairs XCBDY(J), RCBDY(J), where  $1 \leq J \leq \text{NCBDY}$ . A maximum of 40 points can be input. The LSPFIT subroutine uses this input to interpolate for finding the values of RMIN at each axial location X. The LSPFIT routine can treat line segments, both straight and curved. Typical examples of centerbody coordinate input are shown in Figure A-2. If there is no centerbody, the user can avoid automatic computation of the potential core of axisymmetric nozzles (which has no impact on mixing noise) by specifying RMIN as input, but with  $\text{NCBDY} = 0$ . This option causes the computation to begin at  $r = \text{RMIN}(\text{KA})$ , where KA is the axial station number.
10. The input value of CM is modified for velocity ratio and Mach number effects by the relation

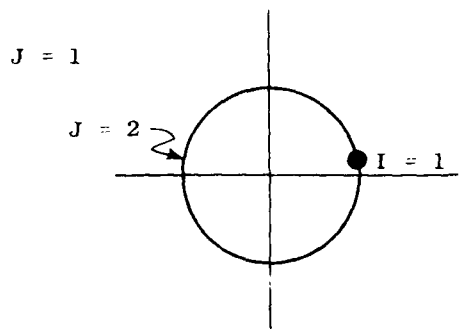
$$\text{DBDX} = \frac{\text{CM}}{(1 + \text{CMVR} * \text{VR})(1 + \text{CMMC} * \text{ACH})}$$

where DBDX is the modified value of  $C_m$ , and VR and ACH are the velocity ratio and Mach number, respectively, of a given boundary. The heat transport spreading parameter is then calculated from the relation

$$C_h = C_H * \text{DBDX}$$

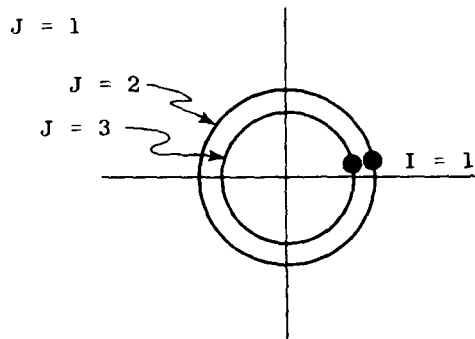
The values of CM, CMMC, CMVR and  $C_H$  recommended and preset in the program are given in Table A-3. These values can be changed by the user to reflect experimental evidence if so desired.

11. The axial locations of the axial stations can be input by the array X(KA), where  $1 \leq \text{KA} \leq \text{KX}$ . The radial mesh step size can also be input by the array DSIG(KA). An automatic grid selection procedure has been devised to obviate the need for supplying all values of X(KA) and DSIG(KA). The only input required is the first axial station X(1), and the grid stretching factors STRFR and STRFX. The grid is then calculated from the following relations:



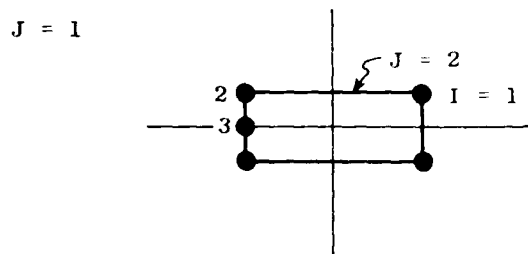
(a) Circular Jet

NEST = 2  
 LPHI = 999  
 ISYM = 1  
 LEAV = 1,36  
 NUM = 1,1,  
 ALP<sub>φ</sub> = 0,0,  
 KN = 1,1,



(b) Coannular Jet

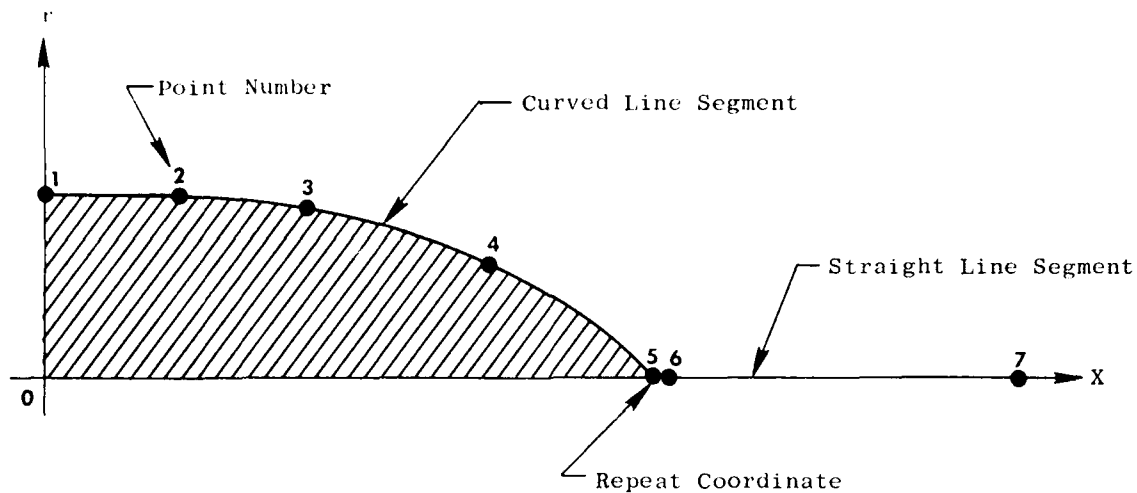
NEST = 3  
 LPHI = 999  
 ISYM = 1  
 LEAV = 1,36,36,  
 NUM = 1,1,1,  
 ALP<sub>φ</sub> = 0,0,0,  
 KN = 1,1,2,



(c) Rectangular Jet

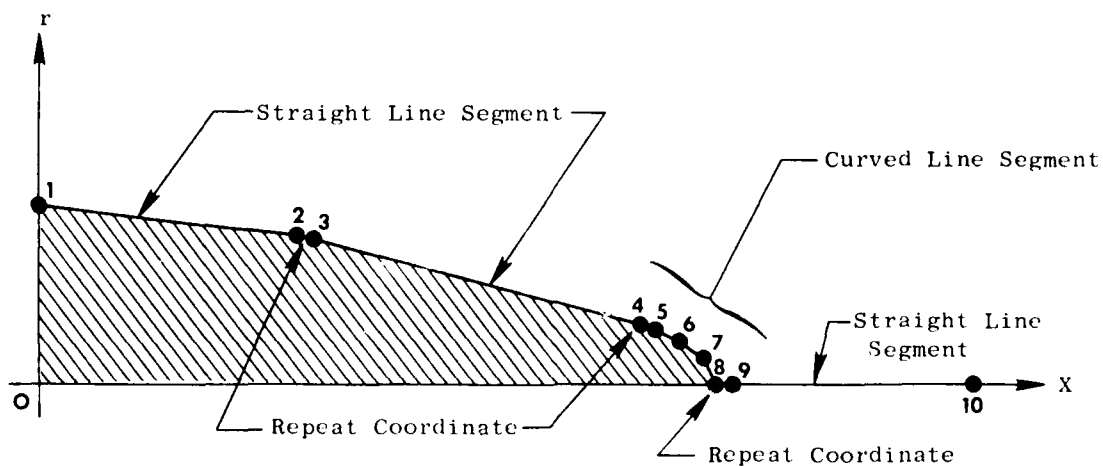
NEST = 2  
 LPHI = 4  
 ISYM = 0  
 LEAV = 1,2,  
 NUM = 1,3,  
 ALP<sub>φ</sub> = 0,0,  
 KN = 1,1,

Figure A-1. Examples of How Boundary Parameters are Specified.



NCBDY = 7,  
 XCBY =  $X_1, X_2, X_3, X_4, X_5, X_6 (=X_5), X_7$ ,  
 RCBY =  $R_1, R_2, R_3, R_4, 0, 0, 0$ ,

(a) Example 1 - Curved Centerbody



NCBDY = 10,  
 XCBY =  $X_1, X_2, X_3 (=X_2), X_4, X_5 (=X_4), X_6, X_7, X_8, X_9 (=X_8), X_{10}$ ,  
 RCBY =  $R_1, R_2, R_3 (=R_2), R_4, R_5 (=R_4), R_6, R_7, R_8, R_9 (=R_8), R_{10}$ ,

(b) Example 2 - Segmented-Cone Centerbody with Curved Tip

Figure A-2. Centerbody Input Coordinate Examples.

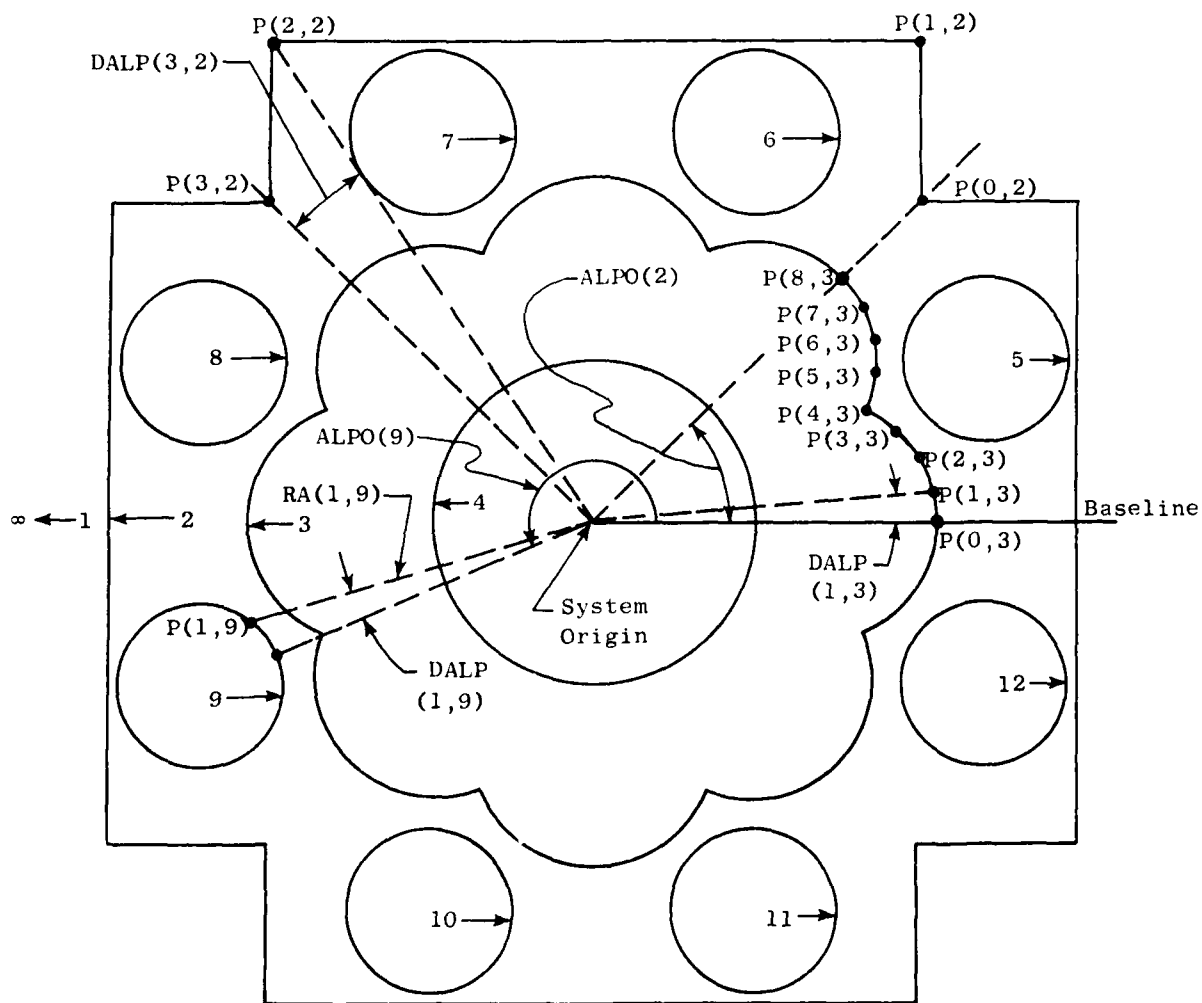


Figure A-3. Example Demonstration of Nozzle Geometry Specification with a Generalized Nozzle Exit Configuration.

$$X(KA) = STRFX * X(KA-1)$$

$$DSIG(KA) = STRFR * X(KA)$$

This provides a grid which exhibits larger and larger step sizes as the plume is developed downstream. Recommended value of STRFR and STRFX are preset and listed in Table A-3.

12. The variable NN determines the type of acoustic calculation desired. Normal (preset) operation is with NN = 0, which give the complete acoustic calculation described in Section 3. The user may desire to perform diagnostic computations to assess the relative importance of convection, shielding, etc. By selecting the appropriate value of NN, the various components of the acoustic calculation can be switched on and off in various combinations. Setting NN = 4 gives only the aerodynamic calculation, and the acoustic calculations are bypassed. The various options for NN are listed below:

NN = 0 - complete acoustic calculation.

NN = 1 - convective amplification, no shielding.

NN = 2 - no convective amplification, no shielding.

NN = 3 - no convective amplification, with shielding.

NN = 4 - no acoustic calculation, aerodynamics only.

13. The printout of aerodynamic flow field data is controlled by NPRINT. When NPRINT = 0, no aerodynamic printout is provided. If NPRINT = 1, aerodynamic printout is provided at every axial station. If NPRINT = 2, aerodynamic printout is provided at every second axial station (i.e., KA = 1, 3, 5, 7, etc). For PRINT = 3, printout is provided at every third station, etc.
14. For dual flow nozzles, if the inner stream has a higher velocity than the outer stream, use ALPHMC = 0.5 and BETAMC = 0.325 (preset values). These variables are weighting factors in the convection Mach number calculation, which is computed from the relation

$$MC = ALPHMC * MACH + BETAMC * EMACH$$

where MACH is the local acoustic Mach number  $U/C_a$  and EMACH is the exit plane reference Mach number  $U_j/C_a$ . If the outer stream has a higher velocity than the inner stream, use ALPHMC = 0.5 and BETAMC = 0.325/VR, where  $VR = (U_{outer}/U_{inner})_j$ . For multielement suppressor nozzles,  $VR = U_j/U_m$ , where  $U_m$  is the post-merged potential core velocity. If  $U_m$  is not known, BETAMC = 0.2 to 0.25 is usually a good approximation.

15. For dual flow nozzles, input BETAIN = 4.0 (preset) for all values of X, provided the inner stream velocity is higher than the outer stream velocity at the exit plane. If the outer stream velocity is higher than the inner stream velocity at the exit plane, input BETAIN = 0 for all axial stations where  $X \leq 10 \cdot \text{DEQ}(\text{NBREF})$ , and BETAIN = 4.0 thereafter, where NBREF is the outer stream boundary number. For multielement nozzles, input BETAIN = 0 for axial distances less than  $10 \cdot \text{DEQ}(1)$ , where DEQ(1) is the equivalent diameter based on total flow area at the exit plane.
16. For each boundary element DEQ, DS and NCELL are input. The first value of DEQ is the total flow area equivalent diameter. The first value of NCELL determines whether or not the shock cell noise is computed. If NCELL(1) is input zero, no shock noise is computed; for NCELL(1) > 0, the shock cell noise routine is called. The shock noise of each boundary element is computed separately and added to the total noise. If any boundary has a value of NCELL = 0, that boundary element is bypassed in the shock noise calculation. It is recommended that NCELL = 8 be used for each element unless the actual number is known.

## A.2 EXAMPLE CASE INPUT SELECTION

To illustrate how geometric input parameters are selected for a complex nozzle geometry, an example is presented, taken from Reference (1). The example nozzle exit geometry is shown in Figure A-3. Consideration of this figure indicates information over a  $45^\circ$  sector of the flow field will be sufficient to describe the complete flow field. This is one-eighth of a circle, thus  $\text{LPHI} = 8$ . Neither axial total similarity or dissimilarity exists so ISYM is 0. Counting the number of closed contours indicates a value of NEST of 12, where one is included for the ambient or external field. Values of PT and TT must be provided for the exit state existing just within each of these contours. Values of XE, ALPO, LEAV, NUM, KN, DEQ, DS, and NCELL must be provided for all the contours except the first which is the boundary at infinity. Values of these parameters for the contours shown in Figure A-3 are now considered in the following discussion.

Boundary 2: Description of this boundary starting at  $45^\circ$  to the system baseline is convenient. Thus  $\text{ALPO} = \pi/4$  radians. Since each  $90^\circ$  sector of the contour is identical with the proceeding one,  $\text{LEAV} = 4$ . Since the program assumes straight lines to exist between successive boundary points, description of this boundary is possible with only three points for each quadrant. These are P(1,2), P(2,2), and P(3,2). Each point is described by its distance from the system origin and the angle between the line joining it with the origin and the line joining the proceeding point with the origin. Note that no value of RA is given for the point P(0,2) since it will be identical to RA(3,2). The value of NUM for boundary 2 will therefore be 3.

Boundary 3: This contour has eight symmetric leaves, thus  $\text{LEAV} = 8$ . ALPO of 0.0 is as convenient as any other value. The eight points indicated P(1,3) through P(8,3) probably are sufficient to describe the boundary. Thus  $\text{NUM} = 8$ .



Boundary 4: Since this is a circle about the origin it can be divided into a convenient number of leaves and only one point given for each (NUM = 1). If a hundred boundary points are desired; set LEAV = 100, DALP(1,4)= $\pi/50$  and RA(1,4) equal to the circle radius.

Boundary 5 through 12: Each of these contours must be described individually unless certain artificial changes are made in the arrangement. A partial representation of Boundary 9 is shown in Figure A-3. Note that successive points on the boundary are obtained by progressing around the boundary in a counter-clockwise fashion. In order to reduce the labor of representing each circle separately, a straight line can be drawn connecting each circle. Two contours can then be visualized, one consisting of the outer halves of the circles and the lines, the other consisting of the inner halves of the circles and the lines. Each contour has eight leaves and only one need be represented by the programmer. Since this technique requires the computer to integrate along each straight line twice in the course of computation, it will definitely increase the computational time over the method wherein each contour is represented separately.

## APPENDIX B

### OUTPUT DESCRIPTION

The output format is generally self-explanatory. The input data is first printed out, using the same nomenclature previously defined in Table 2. Nozzle exit plane flow conditions (static temperature, velocity, Mach number, momentum flux, and enthalpy flux) are then printed out for each boundary contour.

At each axial location specified, the radial and tangential distributions of flow field properties are printed out. After the flow field information, the noise characteristics of that particular axial station are then listed.

Following all of the axial station flow field data, a summary table of the noise characteristics (SPL spectra, PNL, PWL, OASPL) is given.

Appendix C contains an input deck card listing and output printout for a sample case run. This particular case is for a 7-tube nozzle presented in Reference 2. Only a portion of the total output is shown for brevity, but the formats of the various output data are all included.

Two warning flags are built into the program. The first is a case termination flag, which occurs whenever an input total pressure (PT) is less than the input static pressure (PS). The flag message is as follows:

\*\*\*\*ERROR - MACH NO. SQUARE IS NOT GREATER THAN ZERO - CASE WILL  
TERMINATE\*\*\*\*

The second flag is a warning detected in subroutine SLICE, which occurs whenever the number of turning points (NTP) is found to be greater than 2. The flag message is as follows:

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA = \_\_\_\_\_, X = \_\_\_\_\_, ITH = \_\_\_\_\_, THETA = \_\_\_\_\_, NTP = \_\_\_\_\_

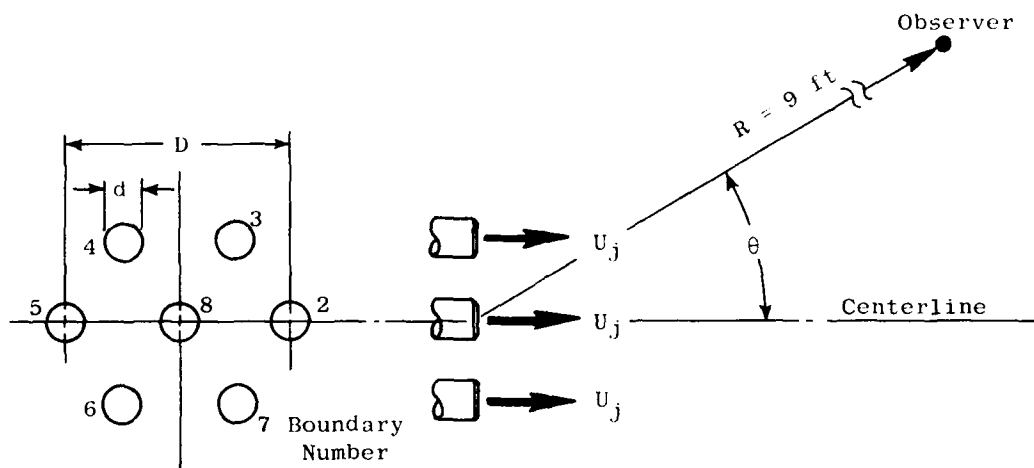
where KA is the axial station number, X is the axial location, ITH is the observer angle index, THETA is the observer angle in degrees ( $\theta_I$ ), and NTP is the number of turning points found. The two outermost turning points are used and those inboard of these two are discarded in such cases, since the acoustic shielding model can only accommodate up to 2 turning points. The noise output at those values of  $\theta_I$  where this warning appears should be

treated as suspect, since the acoustic shielding effects are not properly modeled. This is most likely to occur in the initial mixing regions of multitube nozzles where multiple peaks in the aximuthally-averaged velocity profiles are likely to occur.

## APPENDIX C

### SAMPLE OUTPUT LISTING

An example case of a 7-tube multielement nozzle is described herein, selected from one of the data/theory comparison cases presented in Reference (3). The nozzle consists of a hexagonal array of 0.875-inch diameter tubes, with a spacing/diameter ratio of 3. The acoustic arena is a 9 ft. radius arc. The geometry is illustrated in the sketch below.



$$d = 0.875 \text{ in.}$$

$$D = 3.0 \text{ in.}$$

The input data cards for this case are listed in Table C-1. Note that all geometry input lengths are in feet, and all input geometry angles are in radians. The output listing for this case follows Table C-1.

Table C-1. Input Data Card Listing Sample Case.

```

SR329 01 10-06-77 16.471 *** INPUT DATA CARD LISTING -- M*G*B ***
      CRD 7-TURF AR#2,3 No72LE = VJ#2200 FPS = TTJ#1600 DEG-R
$INPUT
NEST=8, LPHI=12, ISYM=0, IQUIT=100,
RU2M=3, DTHM=0.1, PS=2116,
ATOTAL=0.029231, DE2=8*0.0729167, DS=8*0.0729167, NCELL=8*3,
KN=8*1, XE=8*0,
GAM=1.35, CP=6619,

ALPO=0.0,5.96144,0.725447,1.77264,2.8198,3.8670,4.9142,0.0,
LEAV=0.6*1.24, NUM=1.6*24,1, KN=8*1, XE=8*0,
DALP(1,2)=
.033596,.045590,.054084,.059862,.063450,.065168,
.065168,.063450,.059862,.054084,.045590,.033596,
.017039,-.005317,-.034336,-.068984,-.103591,-.126562,
-.126562,-.103591,-.068984,-.034336,-.005317,.017039,
DALP(1,3)=
.033596,.045590,.054084,.059862,.063450,.065168,
.065168,.063450,.059862,.054084,.045590,.033596,
.017039,-.005317,-.034336,-.068984,-.103591,-.126562,
-.126562,-.103591,-.068984,-.034336,-.005317,.017039,
DALP(1,4)=
.033596,.045590,.054084,.059862,.063450,.065168,
.065168,.063450,.059862,.054084,.045590,.033596,
.017039,-.005317,-.034336,-.068984,-.103591,-.126562,
-.126562,-.103591,-.068984,-.034336,-.005317,.017039,
DALP(1,5)=
.033596,.045590,.054084,.059862,.063450,.065168,
.065168,.063450,.059862,.054084,.045590,.033596,
.017039,-.005317,-.034336,-.068984,-.103591,-.126562,
-.126562,-.103591,-.068984,-.034336,-.005317,.017039,
DALP(1,6)=
.033596,.045590,.054084,.059862,.063450,.065168,
.065168,.063450,.059862,.054084,.045590,.033596,
.017039,-.005317,-.034336,-.068984,-.103591,-.126562,
-.126562,-.103591,-.068984,-.034336,-.005317,.017039,
DALP(1,7)=
.033596,.045590,.054084,.059862,.063450,.065168,
.065168,.063450,.059862,.054084,.045590,.033596,
.017039,-.005317,-.034336,-.068984,-.103591,-.126562,
-.126562,-.103591,-.068984,-.034336,-.005317,.017039,
RA(1,2)=
.12392,.13145,.13759,.14212,.14489,.14583,
.14489,.14212,.13759,.13145,.12392,.11529,
.10596,.09646,.08748,.07991,.07476,.07292,
.07476,.07991,.08748,.09646,.10596,.11529,
RA(1,3)=
.12392,.13145,.13759,.14212,.14489,.14583,
.14489,.14212,.13759,.13145,.12392,.11529,
.10596,.09646,.08748,.07991,.07476,.07292,
.07476,.07991,.08748,.09646,.10596,.11529,
RA(1,4)=
.12392,.13145,.13759,.14212,.14489,.14583,
.14489,.14212,.13759,.13145,.12392,.11529,
.10596,.09646,.08748,.07991,.07476,.07292,

```

Table C-1. Input Data Card Listing Sample Case (Concluded).

```

SR329 01 10-06-77 16.471 *** INPUT DATA CARD LISTING -- M*G*B ***

.07476,.07991,.08748,.09646,.10596,.11529,
RA(1,5)=
.12392,.13145,.13759,.14212,.14489,.14583,
.14489,.14212,.13759,.13145,.12392,.11529,
.10596,.09646,.08748,.07991,.07476,.07292,
.07476,.07991,.08748,.09646,.10596,.11529,
RA(1,6)=
.12392,.13145,.13759,.14212,.14489,.14583,
.14489,.14212,.13759,.13145,.12392,.11529,
.10596,.09646,.08748,.07991,.07476,.07292,
.07476,.07991,.08748,.09646,.10596,.11529,
RA(1,7)=
.12392,.13145,.13759,.14212,.14489,.14583,
.14489,.14212,.13759,.13145,.12392,.11529,
.10596,.09646,.08748,.07991,.07476,.07292,
.07476,.07991,.08748,.09646,.10596,.11529,
DALP(1,8)=0.2618, RA(1,8)=0.036453,

ALPHMC=0.5, BETAMC=0.25,
FMIN=100, FMAX=80000, NUMANG=1, DIST=9.0,
KX=24, X=0.0729167, STRFR=0.01,
DSIG=10*0.00729167, 14*0, NOV=10*20, 14*0,
BETA1N=15*0.0,
NPRINT=
NCASE=1,

PT=2116.7*5732, TT#540.7*1605,
$

```

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CND 7-TURE AP=2.1 NOZZLE - VJ=2200 FPS - TTJ=1400 DEG-P

INPUT DATA

KX= 24 NEST= 6 LPHI= 12 ISYM= J NPRINT= 6 CM= .075  
CM= 1.150 GAM= 1.350 CP= 6619.0 DTHM= .1000 RU2M= 3.0000 PS= 2116.0

COMPUTATION MESH CONTROL PARAMETERS...../ TURBULENCE CONSTANTS

SLICE NO.	X	DSIG	RMIN	NOV	BETA	DELTA	MU
1	.07292	.00729	0.00000	20	0.00	4.00	.20
2	.09187	.00729	0.00000	20	0.00	4.00	.20
3	.11575	.00729	0.00000	20	0.00	4.00	.20
4	.14583	.00729	0.00000	20	0.00	4.00	.20
5	.18374	.00729	0.00000	20	0.00	4.00	.20
6	.23150	.00729	0.00000	20	0.00	4.00	.20
7	.29167	.00729	0.00000	20	0.00	4.00	.20
8	.36748	.00729	0.00000	20	0.00	4.00	.20
9	.46299	.00729	0.00000	20	0.00	4.00	.20
10	.58333	.00729	0.00000	20	0.00	4.00	.20
11	.73495	.00735	0.00000	0	0.00	4.00	.20
12	.92594	.00935	0.00000	0	0.00	4.00	.20
13	1.16667	.01157	0.00000	0	0.00	4.00	.20
14	1.46941	.01475	0.00000	0	0.00	4.00	.20
15	1.85107	.01852	0.00000	0	0.00	4.00	.20
16	2.33333	.02333	0.00000	0	4.00	4.00	.20
17	2.91992	.02940	0.00000	0	4.00	4.00	.20
18	3.73393	.03734	0.00000	0	4.00	4.00	.20
19	4.86667	.04667	0.00000	0	4.00	4.00	.20
20	5.87963	.05882	0.00000	0	4.00	4.00	.20
21	7.40787	.07408	0.00000	0	4.00	4.00	.20
22	9.33333	.09333	0.00000	0	4.00	4.00	.20
23	11.75926	.11759	0.00000	0	4.00	4.00	.20
24	14.81574	.14816	0.00000	0	4.00	4.00	.20

XE( 2)= 0.00 ALPO( 2)= 5.9614 LEAV( 2)= 1 NUM( 2)= 24 KN( 2)= 1  
DALP( 1, 2)= .0336 RA( 1, 2)= .1239 DALP( 2, 2)= .0456 RA( 2, 2)= .1315  
DALP( 3, 2)= .0541 RA( 3, 2)= .1376 DALP( 4, 2)= .0599 RA( 4, 2)= .1421  
DALP( 5, 2)= .0635 RA( 5, 2)= .1449 DALP( 6, 2)= .0652 RA( 6, 2)= .1458  
DALP( 7, 2)= .0652 RA( 7, 2)= .1449 DALP( 8, 2)= .0635 RA( 8, 2)= .1421  
DALP( 9, 2)= .0599 RA( 9, 2)= .1376 DALP(10, 2)= .0541 RA(10, 2)= .1315  
DALP(11, 2)= .0456 RA(11, 2)= .1239 DALP(12, 2)= .0336 RA(12, 2)= .1153  
DALP(13, 2)= .0170 RA(13, 2)= .1060 DALP(14, 2)= -.0053 RA(14, 2)= .0965  
DALP(15, 2)= -.0343 RA(15, 2)= .0875 DALP(16, 2)= -.0690 RA(16, 2)= .0799  
DALP(17, 2)= -.1036 RA(17, 2)= .0748 DALP(18, 2)= -.1266 RA(18, 2)= .0729  
DALP(19, 2)= -.1266 RA(19, 2)= .0748 DALP(20, 2)= -.1036 RA(20, 2)= .0799  
DALP(21, 2)= -.0690 RA(21, 2)= .0875 DALP(22, 2)= -.0343 RA(22, 2)= .0965  
DALP(23, 2)= -.0053 RA(23, 2)= .1060 DALP(24, 2)= .0170 RA(24, 2)= .1153

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - ITJ=1600 DEG-R

XE( 3)=	0.00	ALPO( 3)=	.7254	LEAV( 3)=	1	NUM( 3)=	24	KN( 3)=	1
DALP( 1, 3)=	.0336	RA( 1, 3)=	.1239	DALP( 2, 3)=	.0456	RA( 2, 3)=	.1315		
DALP( 3, 3)=	.0541	RA( 3, 3)=	.1376	DALP( 4, 3)=	.0599	RA( 4, 3)=	.1421		
DALP( 5, 3)=	.0635	RA( 5, 3)=	.1449	DALP( 6, 3)=	.0652	RA( 6, 3)=	.1458		
DALP( 7, 3)=	.0652	RA( 7, 3)=	.1449	DALP( 8, 3)=	.0635	RA( 8, 3)=	.1421		
DALP( 9, 3)=	.0599	RA( 9, 3)=	.1376	DALP(10, 3)=	.0541	RA(10, 3)=	.1315		
DALP(11, 3)=	.0456	RA(11, 3)=	.1239	DALP(12, 3)=	.0336	RA(12, 3)=	.1153		
DALP(13, 3)=	.0170	RA(13, 3)=	.1060	DALP(14, 3)=	-.0053	RA(14, 3)=	.0965		
DALP(15, 3)=	-.0343	RA(15, 3)=	.0875	DALP(16, 3)=	-.0690	RA(16, 3)=	.0799		
DALP(17, 3)=	-.1036	RA(17, 3)=	.0748	DALP(18, 3)=	-.1266	RA(18, 3)=	.0729		
DALP(19, 3)=	-.1266	RA(19, 3)=	.0748	DALP(20, 3)=	-.1036	RA(20, 3)=	.0799		
DALP(21, 3)=	-.0690	RA(21, 3)=	.0875	DALP(22, 3)=	-.0343	RA(22, 3)=	.0965		
DALP(23, 3)=	-.0053	RA(23, 3)=	.1060	DALP(24, 3)=	.0170	RA(24, 3)=	.1153		
XE( 4)=	0.00	ALPO( 4)=	1.7726	LEAV( 4)=	1	NUM( 4)=	24	KN( 4)=	1
DALP( 1, 4)=	.0336	RA( 1, 4)=	.1239	DALP( 2, 4)=	.0456	RA( 2, 4)=	.1315		
DALP( 3, 4)=	.0541	RA( 3, 4)=	.1376	DALP( 4, 4)=	.0599	RA( 4, 4)=	.1421		
DALP( 5, 4)=	.0635	RA( 5, 4)=	.1449	DALP( 6, 4)=	.0652	RA( 6, 4)=	.1458		
DALP( 7, 4)=	.0652	RA( 7, 4)=	.1449	DALP( 8, 4)=	.0635	RA( 8, 4)=	.1421		
DALP( 9, 4)=	.0599	RA( 9, 4)=	.1376	DALP(10, 4)=	.0541	RA(10, 4)=	.1315		
DALP(11, 4)=	.0456	RA(11, 4)=	.1239	DALP(12, 4)=	.0336	RA(12, 4)=	.1153		
DALP(13, 4)=	.0170	RA(13, 4)=	.1060	DALP(14, 4)=	-.0053	RA(14, 4)=	.0965		
DALP(15, 4)=	-.0343	RA(15, 4)=	.0875	DALP(16, 4)=	-.0690	RA(16, 4)=	.0799		
DALP(17, 4)=	-.1036	RA(17, 4)=	.0748	DALP(18, 4)=	-.1266	RA(18, 4)=	.0729		
DALP(19, 4)=	-.1266	RA(19, 4)=	.0748	DALP(20, 4)=	-.1036	RA(20, 4)=	.0799		
DALP(21, 4)=	-.0690	RA(21, 4)=	.0875	DALP(22, 4)=	-.0343	RA(22, 4)=	.0965		
DALP(23, 4)=	-.0053	RA(23, 4)=	.1060	DALP(24, 4)=	.0170	RA(24, 4)=	.1153		



COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1400 DEG-R

XE( 5)=	0.00	ALPO( 5)=	2.8198	LEAV( 5)=	1	NUM( 5)=	24	KN( 5)=	1
DALP( 1, 5)=	.0336	RA( 1, 5)=	.1239	DALP( 2, 5)=	.0456	RA( 2, 5)=	.1315		
DALP( 3, 5)=	.0541	RA( 3, 5)=	.1376	DALP( 4, 5)=	.0599	RA( 4, 5)=	.1421		
DALP( 5, 5)=	.0635	RA( 5, 5)=	.1449	DALP( 6, 5)=	.0652	RA( 6, 5)=	.1458		
DALP( 7, 5)=	.0652	RA( 7, 5)=	.1449	DALP( 8, 5)=	.0635	RA( 8, 5)=	.1421		
DALP( 9, 5)=	.0599	RA( 9, 5)=	.1376	DALP(10, 5)=	.0541	RA(10, 5)=	.1315		
DALP(11, 5)=	.0456	RA(11, 5)=	.1239	DALP(12, 5)=	.0336	RA(12, 5)=	.1153		
DALP(13, 5)=	.0170	RA(13, 5)=	.1060	DALP(14, 5)=	-.0053	RA(14, 5)=	.0965		
DALP(15, 5)=	-.0343	RA(15, 5)=	.0875	DALP(16, 5)=	-.0690	RA(16, 5)=	.0799		
DALP(17, 5)=	-.1036	RA(17, 5)=	.0748	DALP(18, 5)=	-.1266	RA(18, 5)=	.0729		
DALP(19, 5)=	-.1266	RA(19, 5)=	.0748	DALP(20, 5)=	-.1036	RA(20, 5)=	.0799		
DALP(21, 5)=	-.0690	RA(21, 5)=	.0875	DALP(22, 5)=	-.0343	RA(22, 5)=	.0965		
DALP(23, 5)=	-.0053	RA(23, 5)=	.1060	DALP(24, 5)=	.0170	RA(24, 5)=	.1153		
XE( 6)=	0.00	ALPO( 6)=	3.8670	LEAV( 6)=	1	NUM( 6)=	24	KN( 6)=	1
DALP( 1, 6)=	.0336	RA( 1, 6)=	.1239	DALP( 2, 6)=	.0456	RA( 2, 6)=	.1315		
DALP( 3, 6)=	.0541	RA( 3, 6)=	.1376	DALP( 4, 6)=	.0599	RA( 4, 6)=	.1421		
DALP( 5, 6)=	.0635	RA( 5, 6)=	.1449	DALP( 6, 6)=	.0652	RA( 6, 6)=	.1458		
DALP( 7, 6)=	.0652	RA( 7, 6)=	.1449	DALP( 8, 6)=	.0635	RA( 8, 6)=	.1421		
DALP( 9, 6)=	.0599	RA( 9, 6)=	.1376	DALP(10, 6)=	.0541	RA(10, 6)=	.1315		
DALP(11, 6)=	.0456	RA(11, 6)=	.1239	DALP(12, 6)=	.0336	RA(12, 6)=	.1153		
DALP(13, 6)=	.0170	RA(13, 6)=	.1060	DALP(14, 6)=	-.0053	RA(14, 6)=	.0965		
DALP(15, 6)=	-.0343	RA(15, 6)=	.0875	DALP(16, 6)=	-.0690	RA(16, 6)=	.0799		
DALP(17, 6)=	-.1036	RA(17, 6)=	.0748	DALP(18, 6)=	-.1266	RA(18, 6)=	.0729		
DALP(19, 6)=	-.1266	RA(19, 6)=	.0748	DALP(20, 6)=	-.1036	RA(20, 6)=	.0799		
DALP(21, 6)=	-.0690	RA(21, 6)=	.0875	DALP(22, 6)=	-.0343	RA(22, 6)=	.0965		
DALP(23, 6)=	-.0053	RA(23, 6)=	.1060	DALP(24, 6)=	.0170	RA(24, 6)=	.1153		

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CEN 7-TURF AR=2.3 NOZZLE - VJ=2200 FPS - ITJ=1600 DEG-R

XF( 7)=	C( 7)	ALP0( 7)= 4.9142	LEAV( 7)= 1	NUM( 7)= 24	KN( 7)= 1	
	DALP( 1, 7)= .0334	PA( 1, 7)= .1239	DALP( 2, 7)= .0456	PA( 2, 7)= .1315		
	DALP( 3, 7)= .0541	PA( 3, 7)= .1376	DALP( 4, 7)= .0599	PA( 4, 7)= .1421		
	DALP( 5, 7)= .0635	PA( 5, 7)= .1449	DALP( 6, 7)= .0652	PA( 6, 7)= .1458		
	DALP( 7, 7)= .0652	PA( 7, 7)= .1449	DALP( 8, 7)= .0635	PA( 8, 7)= .1421		
	DALP( 9, 7)= .0599	PA( 9, 7)= .1376	DALP( 10, 7)= .0541	PA( 10, 7)= .1315		
	DALP( 11, 7)= .0456	PA( 11, 7)= .1239	DALP( 12, 7)= .0336	PA( 12, 7)= .1153		
	DALP( 13, 7)= .0170	PA( 13, 7)= .1060	DALP( 14, 7)= -.0653	PA( 14, 7)= .0965		
	DALP( 15, 7)= -.0343	PA( 15, 7)= .0275	DALP( 16, 7)= -.0690	PA( 16, 7)= .0799		
	DALP( 17, 7)= -.1034	PA( 17, 7)= .0748	DALP( 18, 7)= -.1266	PA( 18, 7)= .0729		
	DALP( 19, 7)= -.1266	PA( 19, 7)= .0748	DALP( 20, 7)= -.1036	PA( 20, 7)= .0799		
	DALP( 21, 7)= -.0690	PA( 21, 7)= .0275	DALP( 22, 7)= -.0343	PA( 22, 7)= .0965		
	DALP( 23, 7)= -.0170	PA( 23, 7)= .1060	DALP( 24, 7)= .0170	PA( 24, 7)= .1153		
XF( 8)=	C( 8)	ALP0( 8)= 0.2000	LEAV( 8)= 24	NUM( 8)= 1	KN( 8)= 1	
	DALP( 1, 8)= .2614	PA( 1, 8)= .0365	DALP(			

COMPUTATION OF AERO-AcouSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CPD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

EXIT CONDITIONS

CON- TOUR	TOTAL PRESS. (PSF)	TOTAL TEMP. (DEG R)	STATIC TEMP. (DEG R)	VELOCITY (FPS)	MACH NUMBER	MOMENTUM FLUX (LR/SQ-FT)	ENTHALPY FLUX (LR/SQ-FT)
1	2116.00	545.00	545.00	.30	.003	.20000E-03	0.
2	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08
3	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08
4	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08
5	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08
6	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08
7	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08
8	5732.00	1605.00	1239.57	2199.45	1.2979	.48123E+04	.15423E+08

BOUNDARY NO. 2 HAS BEEN DESIGNATED AS THE REFERENCE

AL = .20894E+08	ALFA = 1.00000	AK = .00000E-01	PK = 0.
ATOTAL = .02923	DEQ = .07292	INUIT = 100	NN = 0
STPEX = 1.25992	STUPE = .01000		URFF = 2199.45
ALPHMC = .50000	RETAMC = .2500		
CMVCE = .0000000	CMVPE = .2500000		

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CPD 7-TURF AR=2.3 NOZZLE - VJ=2200 FPS - TIJ=1600 DEG-R

AXIAL LOCATION = .7292 (X/DEG = 1.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/10
1	.00001	0.00	2199.45	.0009948	1239.57	1.00000	.00000	.00010
1	.00001	15.00	2199.45	.0009948	1239.57	1.00000	.00000	.00010
1	.00001	30.00	2199.45	.0009948	1239.57	1.00000	.00000	.00010
1	.00001	45.00	2199.45	.0009948	1239.57	1.00000	.00000	.00010
2	.00729	0.00	2199.46	.0009948	1239.57	1.00000	.00154	.10000
2	.00729	15.00	2199.46	.0009948	1239.57	1.00000	.00154	.10000
2	.00729	30.00	2199.46	.0009948	1239.57	1.00000	.00154	.10000
2	.00729	45.00	2199.46	.0009948	1239.57	1.00000	.00154	.10000
3	.01458	0.00	2199.46	.0009948	1239.57	1.00000	.00044	.20000
3	.01458	7.50	2199.46	.0009948	1239.57	1.00000	.00079	.20000
3	.01458	15.00	2199.46	.0009948	1239.57	1.00000	.00122	.20000
3	.01458	22.50	2199.46	.0009948	1239.57	1.00000	.00090	.20000
3	.01458	30.00	2199.46	.0009948	1239.57	1.00000	.00099	.20000
4	.02188	0.00	2199.20	.0009950	1239.31	.99988	.00289	.30000
4	.02188	7.50	2199.20	.0009950	1239.31	.99988	.00303	.30000
4	.02188	15.00	2199.20	.0009950	1239.31	.99988	.00288	.30000
4	.02188	22.50	2199.19	.0009950	1239.31	.99988	.00298	.30000
4	.02188	30.00	2145.74	.0010195	1209.46	.97562	.05247	.40000
5	.02917	0.00	2145.74	.0010195	1209.48	.97561	.05253	.40000
5	.02917	6.00	2145.76	.0010195	1209.48	.97566	.05253	.40000
5	.02917	12.00	2145.75	.0010195	1209.52	.97558	.05261	.40000
5	.02917	18.00	2145.74	.0010195	1209.46	.97562	.05247	.40000
5	.02917	24.00	1377.41	.0011597	1063.24	.62680	.13781	.50000
6	.03646	0.00	1371.48	.0011596	1063.44	.62395	.13785	.50000
6	.03646	6.00	1373.7	.0011602	1062.79	.62428	.13785	.50000
6	.03646	12.00	1373.57	.0011602	1062.79	.62428	.13785	.50000
6	.03646	18.00	1371.49	.0011595	1063.44	.62355	.13785	.50000
6	.03646	24.00	1378.51	.0011597	1063.24	.62680	.13781	.50000
7	.04375	0.00	203.54	.0016983	726.07	.09254	.04225	.60000
7	.04375	5.00	202.12	.0016972	726.54	.09189	.04202	.60000
7	.04375	10.00	212.14	.0016972	726.54	.09190	.04202	.60000
7	.04375	15.00	203.59	.0016972	726.53	.09192	.04200	.60000
7	.04375	20.00	202.17	.0016972	726.53	.09192	.04200	.60000
7	.04375	25.00	203.61	.0016983	726.06	.09257	.04223	.60000
8	.05104	0.00	2.52	.0021214	591.26	.00114	.00253	.70000
8	.05104	5.00	2.53	.0021241	591.51	.00115	.00292	.70000
8	.05104	10.00	2.94	.0021451	574.93	.00134	.00294	.70000
8	.05104	15.00	3.47	.0021627	571.17	.00158	.00287	.70000
8	.05104	20.00	3.64	.0021692	568.44	.00175	.00287	.70000
8	.05104	25.00	3.96	.0021748	566.98	.00187	.00278	.70000
8	.05104	30.00	4.12	.0021794	565.79	.00191	.00191	.80000
9	.05833	0.00	3.24	.0021752	594.21	.00162	.00191	.80000
9	.05833	4.00	1.35	.0022835	561.00	.00000	.00000	.80000
9	.05833	8.00	0.00	.0022835	561.00	.00000	.00000	.80000
9	.05833	12.00	0.00	.0022835	561.00	.00000	.00000	.80000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - ITJ=1600 DEG-K

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	F/DEQ
9	.05833	17.14	0.00	.0022835	540.00	0.00000	0.00000	.80000
9	.05833	21.43	0.00	.0022835	540.00	0.00000	0.00000	.80000
9	.05833	25.71	0.00	.0022835	540.00	0.00000	0.00000	.80000
9	.05833	30.00	0.00	.0022835	540.00	0.00000	0.00000	.80000
10	.06563	0.00	203.37	.0016986	725.94	.09246	.04216	.90000
10	.06563	4.29	168.50	.0017420	707.84	.07638	.03710	.90000
10	.06563	8.57	95.34	.0018676	660.25	.04335	.02447	.90000
10	.06563	12.86	33.49	.0020323	606.73	.01523	.01067	.90000
10	.06563	17.14	5.84	.0021636	569.91	.00266	.00325	.90000
10	.06563	21.43	0.00	.0022835	540.00	0.00000	0.00000	.90000
10	.06563	25.71	0.00	.0022835	540.00	0.00000	0.00000	.90000
10	.06563	30.00	0.00	.0022835	540.00	0.00000	0.00000	.90000
11	.07292	0.00	1378.45	.0011598	1063.19	.62672	.13779	1.00000
11	.07292	3.75	1282.33	.0011754	1049.07	.58302	.13990	1.00000
11	.07292	7.50	1015.37	.0012396	994.75	.46165	.13664	1.00000
11	.07292	11.25	608.69	.0013846	899.58	.27674	.10947	1.00000
11	.07292	15.00	242.76	.0016504	747.13	.11037	.05941	1.00000
11	.07292	18.75	57.20	.0019585	629.60	.02600	.01884	1.00000
11	.07292	22.50	6.44	.0021637	569.90	.00293	.00379	1.00000
11	.07292	26.25	0.00	.0022835	540.00	0.00000	0.00000	1.00000
11	.07292	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.00000
12	.08021	0.00	2145.74	.0010196	1209.42	.97558	.05248	1.10000
12	.08021	3.75	2124.54	.0010266	1201.14	.96594	.06481	1.10000
12	.08021	7.50	2025.14	.0010525	1171.60	.92075	.10460	1.10000
12	.08021	11.25	1717.49	.0011052	1115.68	.78087	.15852	1.10000
12	.08021	15.00	1059.87	.0012270	1004.97	.48188	.16340	1.10000
12	.08021	18.75	353.54	.0015447	798.27	.16074	.08533	1.10000
12	.08021	22.50	53.70	.0019665	627.03	.02441	.01880	1.10000
12	.08021	26.25	2.21	.0021721	567.69	.00100	.00334	1.10000
12	.08021	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.10000
13	.08750	0.00	2199.19	.0009950	1239.30	.99988	.00213	1.20000
13	.08750	3.33	2198.94	.0009952	1239.07	.99977	.00350	1.20000
13	.08750	6.67	2196.64	.0009967	1237.12	.99872	.01146	1.20000
13	.08750	10.00	2175.80	.0010076	1223.80	.98925	.04213	1.20000
13	.08750	13.33	2032.46	.0010508	1173.47	.92408	.11890	1.20000
13	.08750	16.67	1500.16	.0011379	1083.61	.68296	.18610	1.20000
13	.08750	20.00	616.35	.0013828	891.74	.28023	.13029	1.20000
13	.08750	23.33	110.21	.0018367	671.34	.05011	.03566	1.20000
13	.08750	26.67	7.85	.0021552	572.14	.00357	.00463	1.20000
13	.08750	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.20000
14	.09479	0.00	2199.45	.0009948	1239.57	1.00000	.00140	1.30000
14	.09479	3.33	2199.45	.0009948	1239.57	1.00000	.00161	1.30000
14	.09479	6.67	2199.44	.0009948	1239.55	.99999	.00087	1.30000
14	.09479	10.00	2198.75	.0009953	1238.90	.99968	.00583	1.30000
14	.09479	13.33	2175.18	.0010078	1223.48	.98897	.04684	1.30000
14	.09479	16.67	1911.43	.0010745	1147.62	.86905	.15684	1.30000
14	.09479	20.00	1022.06	.0012373	996.57	.46469	.17621	1.30000
14	.09479	23.33	208.70	.0016920	728.79	.09489	.06070	1.30000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
14	.09479	26.67	14.75	.0021165	582.59	.00671	.00707	1.30000
14	.09479	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.30000
15	.10208	3.00	2199.45	.0009948	1239.57	1.00000	.00031	1.40000
15	.10208	3.00	2199.45	.0009948	1239.57	1.00000	.00186	1.40000
15	.10208	6.00	2199.45	.0009948	1239.57	1.00000	.00140	1.40000
15	.10208	9.00	2199.45	.0009948	1239.56	1.00000	.00159	1.40000
15	.10208	12.00	2198.55	.0009954	1238.72	.99959	.00723	1.40000
15	.10208	15.00	2161.63	.0010135	1216.62	.98280	.06160	1.40000
15	.10208	18.00	1801.51	.0010421	1129.12	.81967	.17685	1.40000
15	.10208	21.00	834.46	.0012917	954.61	.37939	.16055	1.40000
15	.10208	24.00	146.71	.0017738	695.16	.06670	.04583	1.40000
15	.10208	27.00	9.45	.0021459	574.63	.00430	.00516	1.40000
15	.10208	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.40000
16	.10938	0.00	2199.45	.0009948	1239.57	1.00000	.00104	1.50000
16	.10938	3.00	2199.45	.0009948	1239.57	1.00000	.00222	1.50000
16	.10938	6.00	2199.45	.0009948	1239.57	1.00000	.00272	1.50000
16	.10938	9.00	2199.45	.0009948	1239.56	1.00000	.00182	1.50000
16	.10938	12.00	2198.81	.0009953	1238.95	.99971	.00629	1.50000
16	.10938	15.00	2161.18	.0010137	1216.41	.98260	.06199	1.50000
16	.10938	18.00	1752.09	.0010996	1121.40	.79660	.18152	1.50000
16	.10938	21.00	710.45	.0013394	920.63	.32301	.14531	1.50000
16	.10938	24.00	98.26	.0018615	662.41	.04468	.03259	1.50000
16	.10938	27.00	4.21	.0021836	564.70	.00192	.00363	1.50000
16	.10938	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.50000
17	.11667	0.00	2199.45	.0009948	1239.57	1.00000	.00206	1.60000
17	.11667	2.73	2199.45	.0009948	1239.57	1.00000	.00239	1.60000
17	.11667	5.45	2199.45	.0009948	1239.57	1.00000	.00178	1.60000
17	.11667	8.18	2199.45	.0009948	1239.56	1.00000	.00157	1.60000
17	.11667	10.91	2198.91	.0009952	1239.04	.99975	.00557	1.60000
17	.11667	13.64	2174.93	.0010080	1223.34	.98885	.04751	1.60000
17	.11667	16.36	1996.35	.0010753	1146.73	.86674	.15670	1.60000
17	.11667	19.09	1039.03	.0012332	999.94	.47241	.17474	1.60000
17	.11667	21.82	235.07	.0016608	742.44	.10687	.06531	1.60000
17	.11667	24.55	20.71	.0020856	591.22	.00942	.00875	1.60000
17	.11667	27.27	0.00	.0022835	540.00	0.00000	0.00000	1.60000
17	.11667	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.60000
18	.12396	0.00	2199.45	.0009948	1239.57	1.00000	.00154	1.70000
18	.12396	2.73	2199.45	.0009948	1239.57	1.00000	.00141	1.70000
18	.12396	5.45	2199.45	.0009948	1239.56	1.00000	.00162	1.70000
18	.12396	8.18	2199.13	.0009950	1239.25	.99985	.00436	1.70000
18	.12396	10.91	2188.71	.0010013	1231.46	.99512	.02817	1.70000
18	.12396	13.64	2051.20	.0010465	1178.33	.93259	.11403	1.70000
18	.12396	16.36	1433.87	.0011478	1074.26	.65192	.18468	1.70000
18	.12396	19.09	478.50	.0014574	846.09	.21756	.10756	1.70000
18	.12396	21.82	62.84	.0019401	635.56	.02857	.02146	1.70000
18	.12396	24.55	2.80	.0021965	561.37	.00127	.00342	1.70000
18	.12396	27.27	0.00	.0022835	540.00	0.00000	0.00000	1.70000
18	.12396	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.70000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
19	.13125	3.00	2199.19	.0009950	1239.32	.99988	.00325	1.80000
19	.13125	2.50	2198.94	.0009951	1239.12	.99979	.00412	1.80000
19	.13125	5.00	2197.42	.0009962	1237.75	.99908	.00926	1.80000
19	.13125	7.50	2185.40	.0010030	1229.37	.99361	.02954	1.80000
19	.13125	10.00	2106.46	.0010321	1194.73	.95772	.08446	1.80000
19	.13125	12.50	1776.53	.0010963	1124.82	.80771	.15885	1.80000
19	.13125	15.00	1038.20	.0012327	1000.33	.47203	.16182	1.80000
19	.13125	17.50	318.73	.0015743	783.25	.14491	.07710	1.80000
19	.13125	20.00	47.64	.0019859	620.91	.02166	.01638	1.80000
19	.13125	22.50	2.88	.0021988	560.79	.00131	.00320	1.80000
19	.13125	25.00	0.00	.0022835	540.00	0.00000	0.00000	1.80000
19	.13125	27.50	0.00	.0022835	540.00	0.00000	0.00000	1.80000
19	.13125	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.80000
20	.13854	0.00	2145.68	.0010196	1209.39	.97555	.05255	1.90000
20	.13854	2.50	2129.85	.0010249	1203.09	.96835	.06116	1.90000
20	.13854	5.00	2061.96	.0010438	1181.32	.93749	.08886	1.90000
20	.13854	7.50	1867.77	.0010820	1139.60	.84920	.13235	1.90000
20	.13854	10.00	1436.12	.0011483	1073.86	.65295	.16129	1.90000
20	.13854	12.50	756.51	.0013212	933.33	.34395	.12913	1.90000
20	.13854	15.00	231.75	.0016626	741.66	.10537	.05730	1.90000
20	.13854	17.50	37.77	.0020185	610.90	.01717	.01295	1.90000
20	.13854	20.00	2.50	.0022007	560.32	.00114	.00315	1.90000
20	.13854	22.50	0.00	.0022835	540.00	0.00000	0.00000	1.90000
20	.13854	25.00	0.00	.0022835	540.00	0.00000	0.00000	1.90000
20	.13854	27.50	0.00	.0022835	540.00	0.00000	0.00000	1.90000
20	.13854	30.00	0.00	.0022835	540.00	0.00000	0.00000	1.90000
21	.14583	0.00	1378.11	.0011599	1063.10	.62657	.13781	2.00000
21	.14583	2.31	1303.87	.0011715	1052.52	.59281	.13796	2.00000
21	.14583	4.62	1100.68	.0012170	1013.17	.50043	.13495	2.00000
21	.14583	6.92	773.97	.0013145	938.05	.35189	.11671	2.00000
21	.14583	9.23	414.00	.0015002	821.91	.18823	.08055	2.00000
21	.14583	11.54	154.16	.0017639	699.08	.07009	.03861	2.00000
21	.14583	13.85	37.12	.0020204	610.32	.01688	.01201	2.00000
21	.14583	16.15	4.97	.0021826	564.95	.00226	.00328	2.00000
21	.14583	18.46	0.00	.0022835	540.00	0.00000	0.00000	2.00000
21	.14583	20.77	0.00	.0022835	540.00	0.00000	0.00000	2.00000
21	.14583	23.08	0.00	.0022835	540.00	0.00000	0.00000	2.00000
21	.14583	25.38	0.00	.0022835	540.00	0.00000	0.00000	2.00000
21	.14583	27.69	0.00	.0022835	540.00	0.00000	0.00000	2.00000
21	.14583	30.00	0.00	.0022835	540.00	0.00000	0.00000	2.00000
22	.15313	0.00	203.27	.0016988	725.85	.09242	.04220	2.10000
22	.15313	2.14	181.15	.0017236	715.40	.08236	.03875	2.10000
22	.15313	4.29	131.99	.0018010	684.65	.06001	.03049	2.10000
22	.15313	6.43	73.29	.0019140	644.25	.03332	.01912	2.10000
22	.15313	8.57	31.17	.0020427	603.66	.01417	.00955	2.10000
22	.15313	10.71	9.03	.0021524	572.88	.00410	.00396	2.10000
22	.15313	12.86	1.10	.0021963	561.44	.00050	.00274	2.10000
22	.15313	15.00	0.00	.0022835	540.00	0.00000	0.00000	2.10000

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

M	P	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
22	.15313	17.14	0.00	.0022835	540.00	0.00000	0.00000	2.10000
22	.15313	19.29	0.00	.0022835	540.00	0.00000	0.00000	2.10000
22	.15313	21.43	0.00	.0022835	540.00	0.00000	0.00000	2.10000
22	.15313	23.57	0.00	.0022835	540.00	0.00000	0.00000	2.10000
22	.15313	25.71	0.00	.0022835	540.00	0.00000	0.00000	2.10000
22	.15313	27.86	0.00	.0022835	540.00	0.00000	0.00000	2.10000
22	.15313	30.00	0.00	.0022835	540.00	0.00000	0.00000	2.10000
23	.16042	0.00	4.61	.0021890	563.29	.00210	.00280	2.20000
23	.16042	2.14	3.77	.0021944	561.93	.00172	.00285	2.20000
23	.16042	4.29	2.16	.0022076	558.56	.00098	.00276	2.20000
23	.16042	6.43	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	8.57	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	10.71	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	12.86	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	15.00	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	17.14	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	19.29	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	21.43	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	23.57	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	25.71	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	27.86	0.00	.0022835	540.00	0.00000	0.00000	2.20000
23	.16042	30.00	0.00	.0022835	540.00	0.00000	0.00000	2.20000



## CIRCUMFERENTIALLY-AVEAGED PARAMETERS

NR	RADIUS	MACH NO.	TEMP.	INTENSITY	FREQUENCY
1	.0001	1.9662	2.2955	.66906E-12	0.
2	.1000	1.9662	2.2955	.24773E-06	3.
3	.2000	1.9662	2.2955	.95416E-08	0.
4	.3000	1.9666	2.2951	.21384E-04	7.
5	.4000	1.9182	2.2398	.16103E+05	2416.
6	.5000	1.2278	1.9688	.17198E+08	25958.
7	.6000	.1809	1.3452	.51043E+04	16407.
8	.7000	.0028	1.0583	.39885E-04	4377.
9	.8000	.0019	1.0777	.41234E-06	524.
10	.9000	.1277	1.2755	.10304E+04	5139.
11	1.0000	.8929	1.8257	.11824E+08	12312.
12	1.1000	1.5573	2.1133	.29016E+08	5707.
13	1.2000	1.7232	2.2014	.42213E+08	2595.
14	1.3000	1.7745	2.2247	.40008E+08	1676.
15	1.4000	1.7964	2.2343	.41582E+08	1326.
16	1.5000	1.8024	2.2367	.42918E+08	1313.
17	1.6000	1.7963	2.2339	.38624E+08	1513.
18	1.7000	1.7761	2.2255	.43543E+08	1888.
19	1.8000	1.7236	2.2014	.30032E+08	2593.
20	1.9000	1.5589	2.1139	.24184E+08	4755.
21	2.0000	.8929	1.8257	.14303E+08	8933.
22	2.1000	.1275	1.2750	.15046E+04	3436.
23	2.2000	.0029	1.0397	.19514E-04	733.

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 1 X= .07292 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 1 X= .07292 ITH= 11 THETA= 120.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 1 X= .07292 ITH= 12 THETA= 130.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 1 X= .07292 ITH= 13 THETA= 140.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 1 X= .07292 ITH= 14 THETA= 150.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 1 X= .07292 ITH= 15 THETA= 160.00 NTP= 3

X( 1)= .0729 UBI( 1)= .25899E+21 FM( 1)= .2419E+01 UAVG( 1)= 1847.59 UMAX( 1)= 2199.46

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 2 X= .09187 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 2 X= .09187 ITH= 11 THETA= 120.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 2 X= .09187 ITH= 12 THETA= 130.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 2 X= .09187 ITH= 13 THETA= 140.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 2 X= .09187 ITH= 14 THETA= 150.00 NTP= 3

X( 2)= .0919 UBI( 2)= .26385E+21 FM( 2)= .2529E+01 UAVG( 2)= 1767.58 UMAX( 2)= 2199.46

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 3 X= .11575 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 3 X= .11575 ITH= 11 THETA= 120.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 3 X= .11575 ITH= 12 THETA= 130.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 3 X= .11575 ITH= 13 THETA= 140.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 3 X= .11575 ITH= 14 THETA= 150.00 NTP= 3

X( 3)= .1157 UBI( 3)= .26192E+21 FM( 3)= .2669E+01 UAVG( 3)= 1674.56 UMAX( 3)= 2199.45

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 4 X= .14583 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 4 X= .14583 ITH= 11 THETA= 120.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 4 X= .14583 ITH= 12 THETA= 130.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 4 X= .14583 ITH= 13 THETA= 140.00 NTP= 3

X( 4)= .1458 U81( 4)= .2572E+21 FM( 4)= .2843E+01 UAVG( 4)= 1572.60 UMAX( 4)= 2199.41

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 5 X= .18374 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 5 X= .18374 ITH= 11 THETA= 120.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 5 X= .18374 ITH= 12 THETA= 130.00 NTP= 3

X( 5)= .1837 U81( 5)= .24966E+21 FM( 5)= .3047E+01 UAVG( 5)= 1467.27 UMAX( 5)= 2197.57

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 6 X= .23150 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT  
 KA= 6 X= .23150 ITH= 11 THETA= 120.00 NTP= 3

X( 6)= .2315 U81( 6)= .23294E+21 FM( 6)= .3277E+01 UAVG( 6)= 1364.33 UMAX( 6)= 2179.00

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - ITJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
1	.00001	0.00	2106.11	.0010468	1177.90	.95756	.00168	.00010
1	.00001	10.00	2106.11	.0010468	1177.90	.95756	.00168	.00010
1	.00001	20.00	2106.11	.0010468	1177.90	.95756	.00168	.00010
1	.00001	30.00	2106.11	.0010468	1177.90	.95756	.00168	.00010
2	.00729	0.00	2079.70	.0010551	1168.73	.94555	.05657	.10000
2	.00729	10.00	2079.72	.0010550	1168.73	.94556	.05658	.10000
2	.00729	20.00	2079.72	.0010550	1168.73	.94556	.05658	.10000
2	.00729	30.00	2079.70	.0010551	1168.73	.94555	.05658	.10000
3	.01458	0.00	1994.78	.0010776	1144.29	.90694	.08729	.20000
3	.01458	7.50	1994.74	.0010776	1144.27	.90692	.08729	.20000
3	.01458	15.00	1994.77	.0010776	1144.28	.90694	.08730	.20000
3	.01458	22.50	1994.73	.0010776	1144.27	.90692	.08730	.20000
3	.01458	30.00	1994.77	.0010776	1144.28	.90694	.08730	.20000
4	.02188	0.00	1838.10	.0011099	1111.01	.83571	.11429	.30000
4	.02188	7.50	1838.13	.0011099	1111.02	.83572	.11430	.30000
4	.02188	15.00	1838.04	.0011099	1111.97	.83568	.11431	.30000
4	.02188	22.50	1838.06	.0011099	1110.95	.83569	.11432	.30000
4	.02188	30.00	1837.99	.0011100	1110.92	.83566	.11432	.30000
5	.02917	0.00	1601.57	.0011489	1073.31	.72817	.13158	.40000
5	.02917	6.00	1601.44	.0011489	1073.23	.72811	.13160	.40000
5	.02917	12.00	1601.30	.0011491	1073.07	.72804	.13166	.40000
5	.02917	18.00	1601.02	.0011493	1072.85	.72792	.13172	.40000
5	.02917	24.00	1600.72	.0011496	1072.64	.72778	.13176	.40000
5	.02917	30.00	1600.68	.0011496	1072.58	.72776	.13178	.40000
6	.03646	0.00	1298.70	.0011959	1031.04	.59046	.13255	.50000
6	.03646	6.00	1298.61	.0011963	1030.74	.59043	.13268	.50000
6	.03646	12.00	1298.97	.0011975	1029.74	.58968	.13295	.50000
6	.03646	18.00	1295.36	.0011988	1028.56	.58895	.13329	.50000
6	.03646	24.00	1294.41	.0011999	1027.64	.58851	.13355	.50000
6	.03646	30.00	1293.49	.0012004	1027.20	.58810	.13363	.50000
7	.04375	0.00	980.18	.0012487	987.46	.44565	.11324	.60000
7	.04375	5.00	978.21	.0012502	986.28	.44475	.11362	.60000
7	.04375	10.00	973.63	.0012537	983.54	.44267	.11462	.60000
7	.04375	15.00	967.62	.0012584	979.85	.43994	.11590	.60000
7	.04375	20.00	961.38	.0012636	975.87	.43710	.11703	.60000
7	.04375	25.00	956.95	.0012673	972.99	.43508	.11782	.60000
7	.04375	30.00	955.55	.0012685	972.08	.43445	.11812	.60000
8	.05104	0.00	758.09	.0012799	963.41	.34467	.06822	.70000
8	.05104	5.00	751.56	.0012834	960.81	.34170	.07114	.70000
8	.05104	10.00	733.93	.0012928	953.80	.33369	.07705	.70000
8	.05104	15.00	710.08	.0013064	943.84	.32285	.08252	.70000
8	.05104	20.00	686.08	.0013216	933.04	.31193	.08631	.70000
8	.05104	25.00	668.47	.0013335	924.72	.30393	.08843	.70000
8	.05104	30.00	662.07	.0013379	921.68	.30101	.08911	.70000
9	.05833	0.00	758.05	.0012799	963.41	.34465	.06817	.80000
9	.05833	4.29	745.61	.0012839	960.44	.33900	.07124	.80000
9	.05833	8.57	710.47	.0012950	952.16	.32302	.07635	.80000
9	.05833	12.86	658.39	.0013121	939.74	.29934	.07855	.80000

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURF AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
9	.05833	17.14	597.88	.0013330	925.00	.27183	.07582	.80000
9	.05833	21.43	540.35	.0013531	911.29	.24567	.06819	.80000
9	.05833	25.71	498.87	.0013676	901.61	.22682	.05718	.80000
9	.05833	30.00	483.69	.0013728	898.19	.21991	.05027	.80000
10	.06563	0.00	980.09	.0012487	987.45	.44561	.11321	.90000
10	.06563	4.29	958.94	.0012541	983.25	.43599	.11533	.90000
10	.06563	8.57	898.45	.0012692	971.57	.40849	.11492	.90000
10	.06563	12.86	805.40	.0012938	953.09	.36618	.11906	.90000
10	.06563	17.14	692.79	.0013244	931.01	.31498	.11248	.90000
10	.06563	21.43	579.98	.0013541	916.63	.26369	.09745	.90000
10	.06563	25.71	492.43	.0013716	899.03	.22389	.07158	.90000
10	.06563	30.00	458.84	.0013756	896.38	.20861	.03069	.90000
11	.07292	0.00	1298.64	.0011960	1031.04	.59044	.13253	1.00000
11	.07292	3.75	1278.97	.0011997	1027.81	.58150	.13588	1.00000
11	.07292	7.50	1213.17	.0012120	1017.42	.55158	.14287	1.00000
11	.07292	11.25	1109.82	.0012334	999.73	.50459	.14800	1.00000
11	.07292	15.00	977.73	.0012630	976.32	.44453	.14727	1.00000
11	.07292	18.75	829.45	.0012980	950.00	.37712	.13834	1.00000
11	.07292	22.50	686.00	.0013309	926.50	.31190	.11965	1.00000
11	.07292	26.25	576.02	.0013536	912.95	.26189	.08882	1.00000
11	.07292	30.00	533.54	.0013553	909.80	.24258	.04985	1.00000
12	.08021	0.00	1601.50	.0011489	1073.30	.72813	.13157	1.10000
12	.08021	3.75	1577.02	.0011528	1069.60	.71701	.13788	1.10000
12	.08021	7.50	1503.70	.0011648	1058.63	.68367	.15133	1.10000
12	.08021	11.25	1383.35	.0011848	1040.71	.62895	.16335	1.10000
12	.08021	15.00	1219.62	.0012135	1016.11	.55451	.16798	1.10000
12	.08021	18.75	1028.14	.0012507	985.89	.46745	.16135	1.10000
12	.08021	22.50	838.33	.0012885	956.97	.38102	.14139	1.10000
12	.08021	26.25	688.35	.0013137	938.60	.31296	.10494	1.10000
12	.08021	30.00	629.41	.0013201	934.09	.28617	.05050	1.10000
13	.08750	0.00	1838.04	.0011099	1111.01	.83568	.11428	1.20000
13	.08750	3.33	1817.98	.0011135	1107.37	.82656	.12296	1.20000
13	.08750	6.67	1756.96	.0011241	1096.90	.79882	.14180	1.20000
13	.08750	10.00	1653.43	.0011412	1080.52	.75174	.16119	1.20000
13	.08750	13.33	1507.73	.0011642	1059.16	.68550	.17533	1.20000
13	.08750	16.67	1326.82	.0011932	1033.45	.60325	.18014	1.20000
13	.08750	20.00	1116.83	.0012287	1003.54	.50778	.17240	1.20000
13	.08750	23.33	915.38	.0012641	975.46	.41619	.15031	1.20000
13	.08750	26.67	760.19	.0012869	958.20	.34563	.11059	1.20000
13	.08750	30.00	699.78	.0012926	953.93	.31816	.03942	1.20000
14	.09479	0.00	1994.74	.0010776	1144.28	.90693	.08729	1.30000
14	.09479	3.33	1974.99	.0010822	1139.49	.89795	.10155	1.30000
14	.09479	6.67	1914.02	.0010953	1125.76	.87023	.12855	1.30000
14	.09479	10.00	1807.55	.0011154	1105.52	.82182	.15554	1.30000
14	.09479	13.33	1652.47	.0011410	1080.71	.75131	.17663	1.30000
14	.09479	16.67	1451.76	.0011721	1052.06	.66005	.18673	1.30000
14	.09479	20.00	1218.12	.0012089	1019.96	.55383	.18205	1.30000
14	.09479	23.33	982.56	.0012485	987.61	.44673	.15998	1.30000

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEO = 4.00000)

M	P	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEO
14	.09479	26.67	798.20	.0012757	966.58	.36291	.11775	1.30000
14	.09479	30.00	725.24	.0012831	966.98	.32973	.00455	1.30000
15	.10208	0.00	2079.68	.0010551	1168.72	.94554	.05655	1.40000
15	.10208	3.00	2064.03	.0010596	1163.69	.93843	.07855	1.40000
15	.10208	6.00	2015.26	.0010726	1149.60	.91626	.10976	1.40000
15	.10208	9.00	1928.64	.0010923	1128.86	.87687	.14000	1.40000
15	.10208	12.00	1799.20	.0011168	1104.08	.81802	.16625	1.40000
15	.10208	15.00	1624.99	.0011454	1076.54	.73881	.18425	1.40000
15	.10208	18.00	1411.64	.0011788	1046.01	.64181	.19610	1.40000
15	.10208	21.00	1172.55	.0012181	1012.27	.53311	.18135	1.40000
15	.10208	24.00	942.79	.0012592	979.23	.42865	.15690	1.40000
15	.10208	27.00	766.69	.0012872	957.97	.34858	.11462	1.40000
15	.10208	30.00	698.15	.0012947	952.41	.31742	.04002	1.40000
16	.10938	0.00	2106.08	.0010469	1177.88	.95755	.00131	1.50000
16	.10938	3.00	2089.92	.0010520	1172.16	.95320	.06982	1.50000
16	.10938	6.00	2039.21	.0010665	1156.23	.92714	.10518	1.50000
16	.10938	9.00	1948.12	.0010882	1133.09	.88573	.13772	1.50000
16	.10938	12.00	1810.36	.0011151	1105.80	.82310	.16571	1.50000
16	.10938	15.00	1623.35	.0011464	1075.63	.73807	.18444	1.50000
16	.10938	18.00	1393.64	.0011837	1041.70	.63363	.18980	1.50000
16	.10938	21.00	1135.88	.0012300	1002.50	.51644	.17962	1.50000
16	.10938	24.00	888.64	.0012808	962.75	.40403	.15401	1.50000
16	.10938	27.00	698.70	.0013180	935.53	.31767	.11212	1.50000
16	.10938	30.00	624.17	.0013288	927.94	.28378	.05158	1.50000
17	.11667	0.00	2079.64	.0010551	1168.69	.94553	.05661	1.60000
17	.11667	2.73	2064.86	.0010594	1163.93	.93881	.07639	1.60000
17	.11667	5.45	2018.88	.0010717	1150.53	.91790	.10564	1.60000
17	.11667	8.18	1937.32	.0010906	1130.61	.88082	.13436	1.60000
17	.11667	10.91	1815.35	.0011144	1106.47	.82536	.15985	1.60000
17	.11667	13.64	1650.35	.0011426	1079.16	.75034	.17834	1.60000
17	.11667	16.36	1445.39	.0011768	1047.82	.65716	.18636	1.60000
17	.11667	19.09	1210.33	.0012201	1010.61	.55029	.18208	1.60000
17	.11667	21.82	965.46	.0012752	966.93	.43895	.16525	1.60000
17	.11667	24.55	743.54	.0013331	924.94	.33806	.13778	1.60000
17	.11667	27.27	578.88	.0013749	896.83	.26319	.09931	1.60000
17	.11667	30.00	515.41	.0013875	888.71	.23434	.05403	1.60000
18	.12396	0.00	1994.58	.0010777	1144.15	.90685	.08734	1.70000
18	.12396	2.73	1977.29	.0010818	1139.85	.89899	.09823	1.70000
18	.12396	5.45	1924.01	.0010935	1127.67	.87477	.12066	1.70000
18	.12396	8.18	1831.25	.0011116	1109.29	.83259	.14455	1.70000
18	.12396	10.91	1695.34	.0011354	1086.06	.77080	.16479	1.70000
18	.12396	13.64	1516.33	.0011654	1058.07	.68941	.17735	1.70000
18	.12396	16.36	1302.89	.0012043	1023.87	.59237	.17931	1.70000
18	.12396	19.09	1057.75	.0012582	974.99	.48691	.16939	1.70000
18	.12396	21.82	818.59	.0013262	929.78	.37218	.14918	1.70000
18	.12396	24.55	606.74	.0013991	881.32	.27586	.12107	1.70000
18	.12396	27.27	452.02	.0014540	848.04	.20551	.08595	1.70000
18	.12396	30.00	392.42	.0014709	838.30	.17842	.04972	1.70000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEG = 4.00000)

M	D	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEG
19	.13125	1.00	1837.39	.0011105	1115.42	.83539	.11439	1.80000
19	.13125	2.50	1820.44	.0011136	1107.38	.82768	.12007	1.80000
19	.13125	5.00	1788.89	.0011228	1098.22	.80424	.13359	1.80000
19	.13125	7.50	1681.42	.0011378	1083.77	.76447	.14907	1.80000
19	.13125	10.00	1556.92	.0011587	1064.21	.70787	.16264	1.80000
19	.13125	12.50	1397.48	.0011866	1039.14	.63537	.16931	1.80000
19	.13125	15.00	1206.70	.0012245	1006.97	.54864	.16868	1.80000
19	.13125	17.50	997.54	.0012764	966.03	.45354	.15935	1.80000
19	.13125	20.00	787.82	.0013429	914.24	.35819	.14249	1.80000
19	.13125	22.50	593.76	.0014217	867.30	.26996	.12005	1.80000
19	.13125	25.00	431.22	.0015017	821.12	.19606	.09427	1.80000
19	.13125	27.50	316.89	.0015995	799.68	.14408	.06595	1.80000
19	.13125	30.00	273.46	.0015771	781.86	.12433	.04087	1.80000
20	.13854	1.00	1598.74	.0011516	1070.72	.72688	.13194	1.90000
20	.13854	2.50	1579.89	.0011548	1067.79	.71831	.13512	1.90000
20	.13854	5.00	1523.25	.0011644	1058.99	.69256	.14277	1.90000
20	.13854	7.50	1429.27	.0011808	1044.23	.64983	.15099	1.90000
20	.13854	10.00	1301.85	.0012052	1023.13	.59190	.15622	1.90000
20	.13854	12.50	1136.77	.0012407	993.84	.51684	.15577	1.90000
20	.13854	15.00	954.54	.0012896	956.17	.43399	.14844	1.90000
20	.13854	17.50	766.15	.0013530	911.36	.34834	.13455	1.90000
20	.13854	20.00	585.08	.0014320	861.07	.26601	.11549	1.90000
20	.13854	22.50	425.42	.0015230	809.65	.19342	.09352	1.90000
20	.13854	25.00	296.85	.0016132	764.39	.13496	.07079	1.90000
20	.13854	27.50	208.01	.0016788	734.48	.09457	.04826	1.90000
20	.13854	30.00	174.26	.0016987	725.87	.07923	.03019	1.90000
21	.14583	0.00	1287.46	.0012079	1020.84	.58535	.13417	2.00000
21	.14583	2.31	1273.23	.0012109	1018.35	.57488	.13532	2.00000
21	.14583	4.62	1221.46	.0012216	1009.39	.55535	.13771	2.00000
21	.14583	6.92	1140.20	.0012400	994.44	.51840	.13956	2.00000
21	.14583	9.23	1033.56	.0012672	973.08	.46989	.13924	2.00000
21	.14583	11.54	905.48	.0013048	944.99	.41169	.13506	2.00000
21	.14583	13.85	764.63	.0013539	910.74	.34764	.12645	2.00000
21	.14583	16.15	619.74	.0014161	870.74	.28177	.11370	2.00000
21	.14583	18.46	481.43	.0014913	826.87	.21889	.09777	2.00000
21	.14583	20.77	357.91	.0015764	782.20	.16273	.08012	2.00000
21	.14583	23.08	254.57	.0016664	739.96	.11574	.06236	2.00000
21	.14583	25.38	175.01	.0017501	704.58	.07957	.04584	2.00000
21	.14583	27.69	121.64	.0018079	682.03	.05530	.03092	2.00000
21	.14583	30.00	101.49	.0018249	675.70	.04614	.02011	2.00000
22	.15313	0.00	937.77	.0012946	952.48	.42637	.11983	2.10000
22	.15313	2.14	924.95	.0012987	949.49	.42653	.11979	2.10000
22	.15313	4.29	887.81	.0013103	941.04	.40365	.11943	2.10000
22	.15313	6.43	828.08	.0013308	926.59	.37649	.11795	2.10000
22	.15313	8.57	749.54	.0013598	906.80	.34079	.11460	2.10000
22	.15313	10.71	656.99	.0013993	881.41	.29870	.10870	2.10000
22	.15313	12.86	556.37	.0014486	851.20	.25296	.10008	2.10000
22	.15313	15.00	454.56	.0015083	817.51	.20667	.08916	2.10000

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

M	P	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
22	.15313	17.14	357.45	.0015777	781.57	.16252	.07634	2.10000
22	.15313	19.29	270.54	.0016543	745.39	.12361	.06280	2.10000
22	.15313	21.43	197.22	.0017346	719.86	.08967	.04961	2.10000
22	.15313	23.57	137.95	.0018142	679.67	.06272	.03736	2.10000
22	.15313	25.71	93.74	.0018844	654.37	.04260	.02675	2.10000
22	.15313	27.86	64.47	.0019313	638.46	.02931	.01786	2.10000
22	.15313	30.00	53.60	.0019445	634.12	.02437	.01197	2.10000
23	.16042	0.00	613.13	.0014195	868.70	.27876	.09412	2.20000
23	.16042	2.14	603.28	.0014242	865.80	.27429	.09360	2.20000
23	.16042	4.29	575.14	.0014387	857.06	.26145	.09196	2.20000
23	.16042	6.43	530.39	.0014629	842.91	.24114	.08886	2.20000
23	.16042	8.57	472.73	.0014970	823.72	.21493	.08401	2.20000
23	.16042	10.71	406.78	.0015409	800.25	.18495	.07730	2.20000
23	.16042	12.86	327.15	.0015942	773.46	.15329	.06887	2.20000
23	.16042	15.00	269.33	.0016558	744.68	.12246	.05929	2.20000
23	.16042	17.14	206.72	.0017239	715.30	.09399	.04904	2.20000
23	.16042	19.29	152.21	.0017958	686.64	.06920	.03887	2.20000
23	.16042	21.43	107.77	.0018681	660.08	.04900	.02951	2.20000
23	.16042	23.57	73.44	.0019367	636.76	.03339	.02149	2.20000
23	.16042	25.71	48.22	.0019964	617.66	.02193	.01484	2.20000
23	.16042	27.86	31.74	.0020367	605.42	.01443	.00958	2.20000
23	.16042	30.00	25.54	.0020484	601.96	.01161	.00650	2.20000
24	.16771	0.00	357.30	.0015779	781.48	.16245	.06487	2.30000
24	.16771	2.00	351.61	.0015824	779.25	.15986	.06431	2.30000
24	.16771	4.00	335.59	.0015957	772.74	.15258	.06270	2.30000
24	.16771	6.00	310.98	.0016176	762.26	.14098	.05991	2.30000
24	.16771	8.00	277.07	.0016481	748.17	.12597	.05592	2.30000
24	.16771	10.00	240.00	.0016861	731.32	.10912	.05096	2.30000
24	.16771	12.00	209.67	.0017312	712.27	.09123	.04505	2.30000
24	.16771	14.00	161.87	.0017820	691.95	.07360	.03854	2.30000
24	.16771	16.00	126.11	.0018367	671.37	.05734	.03189	2.30000
24	.16771	18.00	94.96	.0018929	651.41	.04318	.02550	2.30000
24	.16771	20.00	68.67	.0019496	632.46	.03122	.01954	2.30000
24	.16771	22.00	47.91	.0020039	615.35	.02178	.01446	2.30000
24	.16771	24.00	32.27	.0020531	600.60	.01467	.01031	2.30000
24	.16771	26.00	20.97	.0020947	588.65	.00954	.00709	2.30000
24	.16771	28.00	13.73	.0021219	581.12	.00624	.00464	2.30000
24	.16771	30.00	10.98	.0021299	578.95	.00499	.00327	2.30000
25	.17500	0.00	186.12	.0017495	704.80	.08462	.03924	2.40000
25	.17500	2.00	182.65	.0017538	703.08	.08304	.03873	2.40000
25	.17500	4.00	173.41	.0017661	698.29	.07844	.03741	2.40000
25	.17500	6.00	159.16	.0017860	690.39	.07230	.03532	2.40000
25	.17500	8.00	140.63	.0018134	679.99	.06331	.03232	2.40000
25	.17500	10.00	120.08	.0018468	667.68	.05400	.02878	2.40000
25	.17500	12.00	99.05	.0018850	654.15	.04500	.02488	2.40000
25	.17500	14.00	78.44	.0019274	639.77	.03566	.02070	2.40000
25	.17500	16.00	59.91	.0019714	625.49	.02724	.01663	2.40000
25	.17500	18.00	44.13	.0020153	611.86	.02006	.01290	2.40000



## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TURB AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
25	.17500	22.00	31.18	.0020583	599.09	.01418	.00964	2.40000
25	.17500	22.00	21.12	.0020987	587.55	.00960	.00694	2.40000
25	.17500	24.00	13.77	.0021344	577.71	.00626	.00481	2.40000
25	.17500	26.00	8.66	.0021636	569.92	.00394	.00334	2.40000
25	.17500	28.00	5.41	.0021926	564.96	.00246	.00232	2.40000
25	.17500	30.00	4.18	.0021877	563.64	.00190	.00192	2.40000
26	.18229	0.00	86.65	.0019098	645.67	.03940	.02081	2.50000
26	.18229	1.87	85.29	.0019131	644.56	.03869	.02052	2.50000
26	.18229	3.75	80.94	.0019217	641.64	.03680	.01974	2.50000
26	.18229	5.62	74.69	.0019357	637.02	.03396	.01860	2.50000
26	.18229	7.50	66.40	.0019552	630.67	.03019	.01697	2.50000
26	.18229	9.37	57.15	.0019786	623.19	.02598	.01510	2.50000
26	.18229	11.25	47.65	.0020048	615.05	.02166	.01303	2.50000
26	.18229	13.12	38.29	.0020337	606.33	.01741	.01087	2.50000
26	.18229	15.00	29.65	.0020641	597.40	.01348	.00879	2.50000
26	.18229	16.87	22.17	.0020942	588.81	.01008	.00693	2.50000
26	.18229	18.75	16.03	.0021229	580.84	.00729	.00534	2.50000
26	.18229	20.62	11.14	.0021501	573.50	.00507	.00396	2.50000
26	.18229	22.50	7.44	.0021746	567.05	.00338	.00293	2.50000
26	.18229	24.37	4.76	.0021955	561.63	.00216	.00224	2.50000
26	.18229	26.25	2.88	.0022116	557.56	.00131	.00172	2.50000
26	.18229	28.12	1.66	.0022189	555.72	.00076	.00151	2.50000
26	.18229	30.00	1.19	.0022174	556.68	.00054	.00132	2.50000
27	.18958	0.00	36.06	.0020411	604.12	.01640	.00971	2.60000
27	.18958	1.87	35.36	.0020436	603.37	.01608	.00957	2.60000
27	.18958	3.75	33.52	.0020500	601.50	.01524	.00917	2.60000
27	.18958	5.62	30.72	.0020600	598.59	.01397	.00858	2.60000
27	.18958	7.50	27.12	.0020736	594.64	.01233	.00776	2.60000
27	.18958	9.37	23.02	.0020905	589.84	.01046	.00681	2.60000
27	.18958	11.25	18.93	.0021087	584.75	.00861	.00587	2.60000
27	.18958	13.12	14.96	.0021285	579.32	.00680	.00485	2.60000
27	.18958	15.00	11.39	.0021486	573.90	.00518	.00392	2.60000
27	.18958	16.87	8.30	.0021685	568.62	.00379	.00304	2.60000
27	.18958	18.75	5.84	.0021868	563.87	.00265	.00246	2.60000
27	.18958	20.62	3.89	.0022033	559.65	.00177	.00192	2.60000
27	.18958	22.50	2.43	.0022167	556.26	.00111	.00165	2.60000
27	.18958	24.37	1.34	.0022241	554.42	.00061	.00166	2.60000
27	.18958	26.25	.34	.0022146	567.06	.00015	.00148	2.60000
27	.18958	28.12	0.00	.0022835	540.00	0.00000	0.00000	2.60000
27	.18958	30.00	0.00	.0022835	540.00	0.00000	0.00000	2.60000

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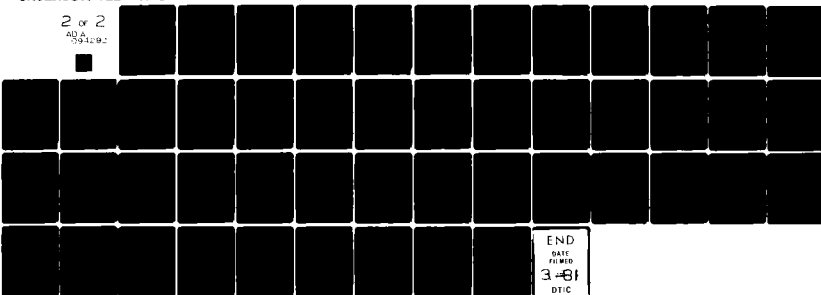
GENERAL ELECTRIC CO CINCINNATI OH AIRCRAFT ENGINE GROUP F/6 20/1  
HIGH VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION. TASK 2 S--ETC(U)  
MAY 78 P R GLIEBE DOT-05-30034  
R78AE6324

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## CIRCUMFERENTIALLY-AVERAGED PARAMETERS

NR	RADIUS	MACH NO.	TEMP.	INTENSITY	FREQUENCY
1	.0001	1.8828	2.1813	.68664E-07	1.
2	.1000	1.8592	2.1644	.26994E+05	722.
3	.2000	1.7832	2.1191	.11244E+07	1793.
4	.3000	1.6431	2.0574	.11132E+08	3336.
5	.4000	1.4313	1.9870	.39960E+08	5082.
6	.5000	1.1587	1.9059	.53881E+08	6414.
7	.6000	.8649	1.8144	.24459E+08	6497.
8	.7000	.6355	1.7476	.26335E+07	4183.
9	.8000	.5695	1.7321	.11638E+07	1968.
10	.9000	.6926	1.7611	.25946E+08	4375.
11	1.0000	.9058	1.8300	.12463E+09	5019.
12	1.1000	1.1205	1.9054	.28211E+09	4338.
13	1.2000	1.2928	1.9686	.43157E+09	3225.
14	1.3000	1.4069	2.0138	.54259E+09	2189.
15	1.4000	1.4638	2.0402	.61131E+09	1565.
16	1.5000	1.4704	2.0443	.63218E+09	1422.
17	1.6000	1.4314	2.0251	.59685E+09	1913.
18	1.7000	1.3472	1.9843	.50905E+09	2664.
19	1.8000	1.2142	1.9246	.39118E+09	3517.
20	1.9000	1.0335	1.8461	.26257E+09	4260.
21	2.0000	.8152	1.7450	.13209E+09	4643.
22	2.1000	.5862	1.6208	.39271E+08	4499.
23	2.2000	.3809	1.4848	.57567E+07	3848.
24	2.3000	.2220	1.3533	.37244E+06	2885.
25	2.4000	.1158	1.2414	.10119E+05	1887.
26	2.5000	.0541	1.1557	.11334E+03	1078.
27	2.6000	.0226	1.0958	.54414E+00	556.

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA= 7 X= .29167 ITH= 11 THEIA= 120.00 NTP= 3

X( 7)=	.2917	U8I( 7)=	.19492E+21	FM( 7)=	.3531E+01	UAVG( 7)=	1266.03	UMAX( 7)=	2106.11
X( 8)=	.3675	U8I( 8)=	.13113E+21	FM( 8)=	.3820E+01	UAVG( 8)=	1170.16	UMAX( 8)=	1951.26
X( 9)=	.4630	U8I( 9)=	.60935E+20	FM( 9)=	.4151E+01	UAVG( 9)=	1077.16	UMAX( 9)=	1731.67
X(10)=	.5833	U8I(10)=	.17529E+20	FM(10)=	.4530E+01	UAVG(10)=	986.98	UMAX(10)=	1506.85
X(11)=	.7350	U8I(11)=	.38719E+19	FM(11)=	.4972E+01	UAVG(11)=	899.31	UMAX(11)=	1347.75
X(12)=	.9260	U8I(12)=	.12720E+19	FM(12)=	.5529E+01	UAVG(12)=	808.47	UMAX(12)=	1276.87

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CPD 7-TURE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
1	.00001	0.00	1238.43	.0012299	1002.62	.56306	.00079	.00016
1	.00001	10.00	1238.43	.0012299	1002.62	.56306	.00079	.00016
1	.00001	20.00	1238.43	.0012299	1002.62	.56306	.00079	.00016
1	.00001	30.00	1238.43	.0012299	1002.62	.56306	.00079	.00016
2	.01167	0.00	1236.43	.0012310	1001.65	.56215	.01959	.16000
2	.01167	10.00	1236.43	.0012310	1001.65	.56215	.01960	.16000
2	.01167	20.00	1236.44	.0012310	1001.66	.56216	.01961	.16000
2	.01167	30.00	1236.44	.0012310	1001.66	.56216	.01960	.16000
3	.02333	0.00	1230.90	.0012345	998.88	.55964	.02794	.32000
3	.02333	7.50	1230.89	.0012345	998.87	.55963	.02794	.32000
3	.02333	15.00	1230.90	.0012345	998.88	.55964	.02797	.32000
3	.02333	22.50	1230.92	.0012345	998.88	.55965	.02797	.32000
3	.02333	30.00	1230.98	.0012344	998.90	.55967	.02798	.32000
4	.03500	0.00	1221.34	.0012405	994.04	.55529	.03476	.48000
4	.03500	7.50	1221.47	.0012404	994.07	.55535	.03477	.48000
4	.03500	15.00	1221.39	.0012404	994.07	.55532	.03482	.48000
4	.03500	22.50	1221.41	.0012404	994.08	.55532	.03489	.48000
4	.03500	30.00	1221.32	.0012404	994.07	.55528	.03491	.48000
5	.04667	0.00	1206.88	.0012493	986.99	.54872	.04115	.64000
5	.04667	6.00	1206.94	.0012493	987.02	.54875	.04119	.64000
5	.04667	12.00	1206.98	.0012493	987.05	.54876	.04135	.64000
5	.04667	18.00	1206.86	.0012492	987.07	.54871	.04154	.64000
5	.04667	24.00	1206.74	.0012492	987.10	.54865	.04169	.64000
5	.04667	30.00	1206.84	.0012492	987.12	.54870	.04170	.64000
6	.05833	0.00	1187.62	.0012613	977.66	.53996	.04768	.80000
6	.05833	6.00	1187.62	.0012612	977.69	.53996	.04783	.80000
6	.05833	12.00	1187.26	.0012611	977.75	.53980	.04814	.80000
6	.05833	18.00	1187.16	.0012610	977.86	.53971	.04850	.80000
6	.05833	24.00	1187.09	.0012608	977.98	.53972	.04878	.80000
6	.05833	30.00	1187.07	.0012608	978.03	.53971	.04888	.80000
7	.07000	0.00	1162.27	.0012765	966.01	.52843	.05460	.96000
7	.07000	5.00	1162.31	.0012764	966.08	.52845	.05478	.96000
7	.07000	10.00	1161.97	.0012762	966.24	.52830	.05520	.96000
7	.07000	15.00	1161.48	.0012759	966.44	.52808	.05571	.96000
7	.07000	20.00	1161.28	.0012755	966.70	.52799	.05618	.96000
7	.07000	25.00	1160.97	.0012753	966.86	.52784	.05648	.96000
7	.07000	30.00	1160.92	.0012752	966.94	.52782	.05655	.96000
8	.08167	0.00	1130.21	.0012946	952.48	.51386	.06181	1.12000
8	.08167	5.00	1130.05	.0012944	952.61	.51378	.06208	1.12000
8	.08167	10.00	1129.59	.0012940	952.92	.51358	.06272	1.12000
8	.08167	15.00	1128.75	.0012935	953.32	.51320	.06347	1.12000
8	.08167	20.00	1128.07	.0012928	953.79	.51289	.06411	1.12000
8	.08167	25.00	1127.39	.0012924	954.10	.51258	.06453	1.12000
8	.08167	30.00	1127.07	.0012923	954.20	.51243	.06465	1.12000
9	.09333	0.00	1090.28	.0013155	937.34	.49570	.06894	1.28000
9	.09333	4.29	1090.08	.0013153	937.50	.49561	.06919	1.28000
9	.09333	8.57	1089.36	.0013147	937.91	.49529	.06987	1.28000
9	.09333	12.86	1088.33	.0013139	938.49	.49482	.07072	1.28000

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURF AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
9	.09333	17.14	1087.31	.0013129	939.17	.49436	.07151	1.28000
9	.09333	21.43	1086.04	.0013122	939.73	.49378	.07208	1.28000
9	.09333	25.71	1085.25	.0013115	940.17	.49342	.07242	1.28000
9	.09333	30.00	1084.88	.0013113	940.31	.49325	.07253	1.28000
10	.10500	0.00	1042.41	.0013387	921.08	.47394	.07553	1.44000
10	.10500	4.29	1041.87	.0013385	921.26	.47369	.07585	1.44000
10	.10500	8.57	1040.72	.0013376	921.88	.47317	.07667	1.44000
10	.10500	12.86	1038.96	.0013363	922.76	.47237	.07767	1.44000
10	.10500	17.14	1037.13	.0013348	923.78	.47154	.07854	1.44000
10	.10500	21.43	1035.17	.0013336	924.64	.47065	.07914	1.44000
10	.10500	25.71	1033.91	.0013326	925.30	.47007	.07946	1.44000
10	.10500	30.00	1033.26	.0013323	925.51	.46978	.07954	1.44000
11	.11667	0.00	985.99	.0013642	903.86	.44829	.08105	1.60000
11	.11667	3.75	985.47	.0013639	904.08	.44805	.08133	1.60000
11	.11667	7.50	984.09	.0013629	904.73	.44742	.08206	1.60000
11	.11667	11.25	981.92	.0013615	905.70	.44644	.08298	1.60000
11	.11667	15.00	979.34	.0013598	906.84	.44526	.08384	1.60000
11	.11667	18.75	976.76	.0013580	908.00	.44409	.08448	1.60000
11	.11667	22.50	974.34	.0013565	908.99	.44299	.08488	1.60000
11	.11667	26.25	972.70	.0013555	909.66	.44225	.08504	1.60000
11	.11667	30.00	972.31	.0013551	909.95	.44207	.08510	1.60000
12	.12833	0.00	921.76	.0013917	885.99	.41909	.08510	1.76000
12	.12833	3.75	920.97	.0013914	886.24	.41873	.08538	1.76000
12	.12833	7.50	918.91	.0013901	887.02	.41779	.08610	1.76000
12	.12833	11.25	915.85	.0013883	888.21	.41640	.08701	1.76000
12	.12833	15.00	912.22	.0013861	889.63	.41475	.08781	1.76000
12	.12833	18.75	908.30	.0013838	891.05	.41297	.08835	1.76000
12	.12833	22.50	904.86	.0013820	892.27	.41140	.08861	1.76000
12	.12833	26.25	902.56	.0013807	893.09	.41036	.08866	1.76000
12	.12833	30.00	901.71	.0013802	893.38	.40997	.08866	1.76000
13	.14000	0.00	850.11	.0014216	867.36	.38651	.08730	1.92000
13	.14000	3.33	849.37	.0014212	867.60	.38617	.08750	1.92000
13	.14000	6.67	847.30	.0014201	868.33	.38523	.08805	1.92000
13	.14000	10.00	843.77	.0014183	869.38	.38363	.08876	1.92000
13	.14000	13.33	839.44	.0014161	870.72	.38166	.08943	1.92000
13	.14000	16.67	834.79	.0014138	872.18	.37954	.08988	1.92000
13	.14000	20.00	830.35	.0014115	873.58	.37753	.09009	1.92000
13	.14000	23.33	826.85	.0014096	874.76	.37593	.09009	1.92000
13	.14000	26.67	824.45	.0014084	875.51	.37484	.09001	1.92000
13	.14000	30.00	823.73	.0014079	875.80	.37452	.08998	1.92000
14	.15167	0.00	772.49	.0014541	847.97	.35122	.08750	2.08000
14	.15167	3.33	771.38	.0014538	848.19	.35072	.08767	2.08000
14	.15167	6.67	768.55	.0014525	848.91	.34943	.08813	2.08000
14	.15167	10.00	764.35	.0014506	850.06	.34752	.08871	2.08000
14	.15167	13.33	759.01	.0014482	851.47	.34509	.08918	2.08000
14	.15167	16.67	753.47	.0014455	853.05	.34257	.08943	2.08000
14	.15167	20.00	747.99	.0014430	854.52	.34008	.08941	2.08000
14	.15167	23.33	743.72	.0014409	855.79	.33814	.08923	2.08000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
14	.15167	26.67	740.75	.0014395	856.58	.33679	.08902	2.08000
14	.15167	30.00	739.65	.0014391	856.84	.33629	.08893	2.08000
15	.16333	0.00	690.42	.0014898	827.68	.31391	.08564	2.24000
15	.16333	3.00	689.59	.0014894	827.88	.31353	.08575	2.24000
15	.16333	6.00	686.80	.0014885	828.43	.31226	.08603	2.24000
15	.16333	9.00	682.73	.0014868	829.35	.31041	.08638	2.24000
15	.16333	12.00	677.69	.0014846	830.56	.30812	.08667	2.24000
15	.16333	15.00	671.85	.0014822	831.90	.30546	.08677	2.24000
15	.16333	18.00	665.83	.0014799	833.24	.30272	.08666	2.24000
15	.16333	21.00	660.62	.0014775	834.56	.30035	.08640	2.24000
15	.16333	24.00	656.27	.0014757	835.59	.29838	.08605	2.24000
15	.16333	27.00	653.51	.0014745	836.28	.29712	.08578	2.24000
15	.16333	30.00	652.68	.0014740	836.57	.29675	.08568	2.24000
16	.17500	0.00	606.81	.0015289	806.53	.27589	.08184	2.40000
16	.17500	3.00	605.99	.0015285	806.75	.27552	.08193	2.40000
16	.17500	6.00	602.99	.0015276	807.20	.27411	.08208	2.40000
16	.17500	9.00	598.56	.0015260	808.06	.27214	.08227	2.40000
16	.17500	12.00	592.66	.0015240	809.09	.26946	.08234	2.40000
16	.17500	15.00	586.40	.0015216	810.36	.26661	.08225	2.40000
16	.17500	18.00	579.83	.0015192	811.65	.26362	.08193	2.40000
16	.17500	21.00	574.00	.0015169	812.90	.26097	.08149	2.40000
16	.17500	24.00	569.29	.0015150	813.93	.25883	.08101	2.40000
16	.17500	27.00	566.13	.0015138	814.56	.25740	.08062	2.40000
16	.17500	30.00	565.13	.0015133	814.81	.25694	.08049	2.40000
17	.18667	0.00	524.23	.0015714	784.69	.23834	.07644	2.56000
17	.18667	2.73	523.45	.0015711	784.83	.23799	.07647	2.56000
17	.18667	5.45	520.84	.0015705	785.15	.23680	.07651	2.56000
17	.18667	8.18	516.92	.0015693	785.74	.23562	.07655	2.56000
17	.18667	10.91	511.73	.0015678	786.50	.23266	.07649	2.56000
17	.18667	13.64	505.65	.0015661	787.38	.22990	.07627	2.56000
17	.18667	16.36	499.45	.0015640	788.42	.22708	.07592	2.56000
17	.18667	19.09	493.33	.0015619	789.45	.22430	.07540	2.56000
17	.18667	21.82	487.93	.0015600	790.42	.22184	.07483	2.56000
17	.18667	24.55	483.66	.0015585	791.20	.21990	.07429	2.56000
17	.18667	27.27	481.02	.0015574	791.74	.21870	.07392	2.56000
17	.18667	30.00	480.13	.0015570	791.94	.21829	.07378	2.56000
18	.19833	0.00	444.85	.0016173	762.41	.20226	.06978	2.72000
18	.19833	2.73	444.06	.0016171	762.53	.20190	.06978	2.72000
18	.19833	5.45	441.44	.0016166	762.75	.20070	.06974	2.72000
18	.19833	8.18	437.39	.0016157	763.17	.19886	.06964	2.72000
18	.19833	10.91	432.15	.0016145	763.74	.19648	.06942	2.72000
18	.19833	13.64	426.10	.0016130	764.46	.19373	.06906	2.72000
18	.19833	16.36	419.72	.0016113	765.27	.19083	.06854	2.72000
18	.19833	19.09	413.45	.0016095	766.10	.18798	.06790	2.72000
18	.19833	21.82	407.99	.0016078	766.94	.18550	.06722	2.72000
18	.19833	24.55	403.63	.0016064	767.62	.18352	.06660	2.72000
18	.19833	27.27	400.90	.0016054	768.08	.18227	.06616	2.72000
18	.19833	30.00	399.90	.0016051	768.23	.18182	.06600	2.72000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEG
19	.21000	0.00	370.73	.0016662	740.06	.16855	.06228	2.88000
19	.21000	2.50	370.01	.0016661	740.10	.16823	.06225	2.88000
19	.21000	5.00	367.92	.0016658	740.23	.16728	.06217	2.88000
19	.21000	7.50	364.58	.0016653	740.45	.16576	.06260	2.88000
19	.21000	10.00	360.11	.0016647	740.74	.16373	.06172	2.88000
19	.21000	12.50	354.93	.0016637	741.15	.16137	.06133	2.88000
19	.21000	15.00	349.35	.0016625	741.68	.15883	.06081	2.88000
19	.21000	17.50	343.58	.0016613	742.23	.15621	.06017	2.88000
19	.21000	20.00	338.18	.0016599	742.84	.15376	.05948	2.88000
19	.21000	22.50	333.44	.0016587	743.40	.15160	.05879	2.88000
19	.21000	25.00	329.79	.0016576	743.89	.14994	.05821	2.88000
19	.21000	27.50	327.48	.0016569	744.21	.14889	.05781	2.88000
19	.21000	30.00	326.69	.0016566	744.32	.14853	.05767	2.88000
20	.22167	0.00	303.31	.0017173	718.03	.13790	.05436	3.04000
20	.22167	2.50	302.60	.0017173	718.02	.13758	.05431	3.04000
20	.22167	5.00	300.64	.0017172	718.06	.13669	.05418	3.04000
20	.22167	7.50	297.45	.0017171	718.13	.13524	.05394	3.04000
20	.22167	10.00	293.36	.0017167	718.30	.13338	.05359	3.04000
20	.22167	12.50	288.49	.0017161	718.52	.13116	.05312	3.04000
20	.22167	15.00	283.14	.0017155	718.80	.12873	.05252	3.04000
20	.22167	17.50	277.74	.0017145	719.18	.12628	.05183	3.04000
20	.22167	20.00	272.60	.0017136	719.60	.12394	.05109	3.04000
20	.22167	22.50	268.15	.0017125	720.03	.12192	.05038	3.04000
20	.22167	25.00	264.66	.0017117	720.40	.12033	.04977	3.04000
20	.22167	27.50	262.47	.0017110	720.66	.11933	.04937	3.04000
20	.22167	30.00	261.72	.0017108	720.75	.11899	.04922	3.04000
21	.23333	0.00	243.54	.0017699	696.68	.11073	.04640	3.20000
21	.23333	2.31	243.02	.0017700	696.67	.11049	.04635	3.20000
21	.23333	4.62	241.46	.0017701	696.63	.10978	.04621	3.20000
21	.23333	6.92	239.06	.0017701	696.62	.10869	.04598	3.20000
21	.23333	9.23	235.80	.0017701	696.61	.10721	.04564	3.20000
21	.23333	11.54	231.86	.0017701	696.62	.10542	.04520	3.20000
21	.23333	13.85	227.52	.0017699	696.70	.10344	.04466	3.20000
21	.23333	16.15	222.94	.0017695	696.83	.10136	.04404	3.20000
21	.23333	18.46	218.46	.0017690	697.04	.09932	.04336	3.20000
21	.23333	20.77	214.31	.0017683	697.31	.09744	.04268	3.20000
21	.23333	23.08	210.74	.0017676	697.58	.09582	.04204	3.20000
21	.23333	25.38	208.00	.0017670	697.83	.09457	.04152	3.20000
21	.23333	27.69	206.28	.0017666	698.00	.09379	.04118	3.20000
21	.23333	30.00	205.69	.0017664	698.07	.09352	.04106	3.20000
22	.24500	0.00	191.94	.0018229	676.44	.08727	.03874	3.36000
22	.24500	2.14	191.56	.0018230	676.41	.08709	.03869	3.36000
22	.24500	4.29	190.41	.0018231	676.35	.08657	.03857	3.36000
22	.24500	6.43	188.54	.0018234	676.25	.08572	.03835	3.36000
22	.24500	8.57	186.04	.0018237	676.15	.08458	.03804	3.36000
22	.24500	10.71	183.00	.0018240	676.04	.08320	.03765	3.36000
22	.24500	12.86	179.58	.0018242	675.97	.08165	.03718	3.36000
22	.24500	15.00	175.91	.0018242	675.94	.07998	.03664	3.36000

## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TURF AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
22	.24500	17.14	172.18	.0018241	675.97	.07828	.03605	3.36000
22	.24500	19.29	168.57	.0018239	676.07	.07664	.03544	3.36000
22	.24500	21.43	165.28	.0018235	676.21	.07515	.03484	3.36000
22	.24500	23.57	162.49	.0018231	676.37	.07388	.03430	3.36000
22	.24500	25.71	160.36	.0018226	676.53	.07291	.03386	3.36000
22	.24500	27.86	159.03	.0018223	676.64	.07231	.03358	3.36000
22	.24500	30.00	158.58	.0018222	676.68	.07210	.03348	3.36000
23	.25667	0.00	148.57	.0018751	657.61	.06755	.03165	3.52000
23	.25667	2.14	148.24	.0018752	657.58	.06740	.03160	3.52000
23	.25667	4.29	147.26	.0018754	657.48	.06695	.03147	3.52000
23	.25667	6.43	145.67	.0018759	657.34	.06623	.03126	3.52000
23	.25667	8.57	143.53	.0018764	657.16	.06526	.03096	3.52000
23	.25667	10.71	140.94	.0018769	656.97	.06408	.03058	3.52000
23	.25667	12.86	138.01	.0018774	656.79	.06275	.03013	3.52000
23	.25667	15.00	134.87	.0018778	656.66	.06132	.02962	3.52000
23	.25667	17.14	131.67	.0018780	656.58	.05987	.02906	3.52000
23	.25667	19.29	128.57	.0018780	656.57	.05846	.02849	3.52000
23	.25667	21.43	125.74	.0018779	656.62	.05717	.02794	3.52000
23	.25667	23.57	123.33	.0018776	656.71	.05607	.02744	3.52000
23	.25667	25.71	121.49	.0018774	656.81	.05524	.02704	3.52000
23	.25667	27.86	120.34	.0018771	656.89	.05471	.02678	3.52000
23	.25667	30.00	119.95	.0018771	656.92	.05453	.02669	3.52000
24	.26833	0.00	112.88	.0019255	640.38	.05132	.02529	3.68000
24	.26833	2.00	112.64	.0019256	640.34	.05121	.02526	3.68000
24	.26833	4.00	111.93	.0019260	640.24	.05089	.02515	3.68000
24	.26833	6.00	110.78	.0019264	640.08	.05037	.02497	3.68000
24	.26833	8.00	109.22	.0019271	639.87	.04966	.02473	3.68000
24	.26833	10.00	107.32	.0019278	639.64	.04879	.02442	3.68000
24	.26833	12.00	105.13	.0019285	639.41	.04780	.02406	3.68000
24	.26833	14.00	102.75	.0019291	639.19	.04672	.02364	3.68000
24	.26833	16.00	100.27	.0019296	639.02	.04559	.02319	3.68000
24	.26833	18.00	97.79	.0019300	638.90	.04446	.02272	3.68000
24	.26833	20.00	95.44	.0019302	638.84	.04339	.02224	3.68000
24	.26833	22.00	93.31	.0019302	638.83	.04242	.02179	3.68000
24	.26833	24.00	91.51	.0019301	638.87	.04161	.02139	3.68000
24	.26833	26.00	90.16	.0019299	638.92	.04099	.02108	3.68000
24	.26833	28.00	89.31	.0019298	638.97	.04060	.02088	3.68000
24	.26833	30.00	89.02	.0019297	638.99	.04047	.02081	3.68000
25	.28000	0.00	84.19	.0019734	624.84	.03828	.01978	3.84000
25	.28000	2.00	84.00	.0019735	624.80	.03819	.01975	3.84000
25	.28000	4.00	83.43	.0019739	624.69	.03793	.01966	3.84000
25	.28000	6.00	82.50	.0019745	624.51	.03751	.01950	3.84000
25	.28000	8.00	81.24	.0019752	624.28	.03694	.01928	3.84000
25	.28000	10.00	79.70	.0019760	624.01	.03624	.01901	3.84000
25	.28000	12.00	77.94	.0019769	623.74	.03544	.01868	3.84000
25	.28000	14.00	76.01	.0019777	623.48	.03456	.01832	3.84000
25	.28000	16.00	74.00	.0019785	623.25	.03365	.01792	3.84000
25	.28000	18.00	71.99	.0019790	623.08	.03273	.01751	3.84000



## COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEQ
25	.28000	20.00	70.07	.0019794	622.97	.03186	.01710	3.84000
25	.28000	22.00	68.33	.0019795	622.91	.03107	.01671	3.84000
25	.28000	24.00	66.87	.0019795	622.91	.03040	.01637	3.84000
25	.28000	26.00	65.76	.0019795	622.93	.02990	.01611	3.84000
25	.28000	28.00	65.06	.0019794	622.96	.02958	.01593	3.84000
25	.28000	30.00	64.83	.0019793	622.97	.02947	.01587	3.84000
26	.29167	0.00	61.63	.0020180	611.04	.02802	.01514	4.00000
26	.29167	1.87	61.50	.0020181	611.00	.02796	.01512	4.00000
26	.29167	3.75	61.11	.0020185	610.96	.02778	.01505	4.00000
26	.29167	5.62	60.46	.0020190	610.73	.02749	.01493	4.00000
26	.29167	7.50	59.59	.0020197	610.52	.02709	.01476	4.00000
26	.29167	9.37	58.51	.0020206	610.26	.02660	.01455	4.00000
26	.29167	11.25	57.26	.0020215	609.99	.02603	.01431	4.00000
26	.29167	13.12	55.88	.0020224	609.71	.02540	.01403	4.00000
26	.29167	15.00	54.41	.0020232	609.46	.02474	.01373	4.00000
26	.29167	16.87	52.91	.0020240	609.24	.02406	.01341	4.00000
26	.29167	18.75	51.44	.0020245	609.06	.02339	.01308	4.00000
26	.29167	20.62	50.05	.0020249	608.95	.02276	.01277	4.00000
26	.29167	22.50	48.81	.0020252	608.88	.02219	.01247	4.00000
26	.29167	24.37	47.76	.0020252	608.86	.02172	.01222	4.00000
26	.29167	26.25	46.98	.0020252	608.86	.02136	.01202	4.00000
26	.29167	28.12	46.49	.0020252	608.87	.02114	.01189	4.00000
26	.29167	30.00	46.32	.0020252	608.88	.02106	.01185	4.00000
27	.30333	0.00	44.28	.0020588	598.94	.02013	.01135	4.16000
27	.30333	1.87	44.18	.0020589	598.90	.02009	.01133	4.16000
27	.30333	3.75	43.88	.0020592	598.80	.01995	.01127	4.16000
27	.30333	5.62	43.39	.0020598	598.63	.01973	.01117	4.16000
27	.30333	7.50	42.72	.0020606	598.42	.01942	.01103	4.16000
27	.30333	9.37	41.89	.0020614	598.16	.01904	.01086	4.16000
27	.30333	11.25	40.93	.0020624	597.88	.01861	.01066	4.16000
27	.30333	13.12	39.87	.0020634	597.66	.01813	.01043	4.16000
27	.30333	15.00	38.74	.0020643	597.34	.01761	.01018	4.16000
27	.30333	16.87	37.58	.0020651	597.10	.01709	.00992	4.16000
27	.30333	18.75	36.45	.0020658	596.91	.01657	.00966	4.16000
27	.30333	20.62	35.37	.0020662	596.77	.01608	.00940	4.16000
27	.30333	22.50	34.41	.0020665	596.69	.01564	.00916	4.16000
27	.30333	24.37	33.60	.0020667	596.65	.01528	.00895	4.16000
27	.30333	26.25	32.99	.0020667	596.63	.01500	.00879	4.16000
27	.30333	28.12	32.61	.0020667	596.64	.01482	.00869	4.16000
27	.30333	30.00	32.48	.0020667	596.64	.01477	.00865	4.16000
28	.31500	0.00	31.22	.0020955	588.45	.01419	.00832	4.32000
28	.31500	1.76	31.15	.0020956	588.42	.01416	.00831	4.32000
28	.31500	3.53	30.95	.0020959	588.34	.01407	.00827	4.32000
28	.31500	5.29	30.63	.0020964	588.19	.01392	.00819	4.32000
28	.31500	7.06	30.18	.0020970	588.01	.01372	.00810	4.32000
28	.31500	8.82	29.62	.0020978	587.78	.01347	.00798	4.32000
28	.31500	10.59	28.97	.0020987	587.54	.01317	.00783	4.32000
28	.31500	12.35	28.25	.0020996	587.28	.01284	.00767	4.32000

\* \* \* M G R \* \* \*

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# COMPUTATION OF AERU-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1

C9D 7-TURF AP=2.3 NOZZLE - VJ=2200 FPS - ITJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

M	P	ANGLE	U	DENSITY	TEMP.	U/UREF	TURR.INT.	P/DEQ
28	.31500	14.12	27.47	.0021096	587.02	.01249	.00749	4.32000
28	.31500	15.88	26.66	.0021014	586.78	.01212	.00730	4.32000
28	.31500	17.65	25.84	.0021022	586.57	.01175	.00710	4.32000
28	.31500	19.41	25.55	.0021028	586.41	.01139	.00691	4.32000
28	.31500	21.18	24.31	.0021032	586.28	.01105	.00672	4.32000
28	.31500	22.94	23.64	.0021035	586.20	.01075	.00655	4.32000
28	.31500	24.71	23.09	.0021036	586.16	.01050	.00640	4.32000
28	.31500	26.47	22.68	.0021037	586.15	.01031	.00629	4.32000
28	.31500	28.24	22.42	.0021037	586.14	.01020	.00622	4.32000
28	.31500	30.00	22.34	.0021037	586.14	.01016	.00619	4.32000

## CIRCUMFERENTIALLY-AVERAGED PARAMETERS

NR	RADIUS	MACH NO.	TEMP.	INTENSITY	FREQUENCY
1	.0002	1.1079	1.8567	.36859E-08	0.
2	.1600	1.1052	1.8550	.16573E+03	36.
3	.3200	1.1003	1.8498	.39818E+04	75.
4	.4800	1.0918	1.8409	.27782E+05	117.
5	.6400	1.0788	1.8279	.12514E+06	167.
6	.8000	1.0613	1.8198	.45802E+06	230.
7	.9600	1.0383	1.7898	.14834E+07	312.
8	1.1200	1.0089	1.7655	.42972E+07	416.
9	1.2800	.9722	1.7386	.10842E+08	540.
10	1.4400	.9278	1.7098	.23371E+08	680.
11	1.6000	.8753	1.6794	.42290E+08	828.
12	1.7600	.8151	1.6475	.63877E+08	972.
13	1.9200	.7482	1.6139	.80312E+08	1102.
14	2.0800	.6760	1.5783	.84269E+08	1208.
15	2.2400	.6005	1.5406	.73889E+08	1282.
16	2.4000	.5242	1.5009	.54403E+08	1319.
17	2.5600	.4494	1.4594	.37814E+08	1317.
18	2.7200	.3782	1.4167	.17811E+08	1279.
19	2.8800	.3124	1.3739	.79784E+07	1209.
20	3.0400	.2533	1.3316	.30469E+07	1113.
21	3.2000	.2016	1.2909	.99454E+06	998.
22	3.3600	.1574	1.2523	.27804E+06	872.
23	3.5200	.1207	1.2167	.66704E+05	743.
24	3.6800	.0909	1.1842	.13745E+05	618.
25	3.8400	.0671	1.1550	.24359E+04	501.
26	4.0000	.0487	1.1293	.37173E+03	396.
27	4.1600	.0346	1.1068	.48923E+02	306.
28	4.3200	.0241	1.0874	.55651E+01	231.
X(13)=	1.1667	U8I(13)= .76410E+18	FM(13)= .6247E+01	UAVG(13)= 715.30	UMAX(13)= 1238.43
X(14)=	1.4699	U8I(14)= .56088E+18	FM(14)= .7156E+01	UAVG(14)= 623.99	UMAX(14)= 1165.93
X(15)=	1.8520	U8I(15)= .35723E+18	FM(15)= .8293E+01	UAVG(15)= 537.77	UMAX(15)= 1043.83
X(16)=	2.3333	U8I(16)= .99889E+18	FM(16)= .9976E+01	UAVG(16)= 446.90	UMAX(16)= 892.50
X(17)=	2.9398	U8I(17)= .42769E+18	FM(17)= .1217E+02	UAVG(17)= 366.21	UMAX(17)= 737.45
X(18)=	3.7039	U8I(18)= .14890E+18	FM(18)= .1471E+02	UAVG(18)= 302.27	UMAX(18)= 595.63

COMPUTATION OF AERO-AcouSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TURF AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-P

AXIAL LOCATION = 4.06667 (X/DEG = 63.90995)

M	R	ANGLE	U	DENSITY	TEMP.	U/UREF	TURB.INT.	R/DEG
1	.00005	0.00	474.50	.0017583	711.27	.21573	.08242	.00064
2	.04667	0.00	469.72	.0017611	701.58	.21356	.08109	.64000
3	.09333	0.00	455.47	.0017655	698.44	.20708	.07720	1.28000
4	.14000	0.00	432.79	.0017745	694.91	.19677	.07119	1.92000
5	.18667	0.00	402.88	.0017872	689.95	.18317	.06377	2.56000
6	.23333	0.00	367.44	.0018037	683.64	.16736	.05599	3.20000
7	.28000	0.00	328.34	.0018239	676.66	.14928	.04928	3.84000
8	.32667	0.00	287.48	.0018476	667.39	.13071	.04473	4.48000
9	.37333	0.00	246.62	.0018745	657.82	.11213	.04208	5.12000
10	.42000	0.00	207.33	.0019039	647.65	.09426	.04001	5.76000
11	.46667	0.00	170.82	.0019353	637.15	.07766	.03750	6.40000
12	.51333	0.00	137.95	.0019678	626.63	.06272	.03426	7.03999
13	.56000	0.00	109.22	.0020017	616.34	.04966	.03041	7.67999
14	.60667	0.00	84.77	.0020331	606.50	.03854	.02621	8.31999
15	.65333	0.00	64.52	.0020645	597.29	.02933	.02197	8.95999
16	.70000	0.00	48.15	.0020941	588.82	.02189	.01791	9.59999
17	.74667	0.00	35.23	.0021217	581.17	.01602	.01423	10.23999

# CIRCUMFERENTIALLY-AVERAGED PARAMETERS

NR	RADIUS	MACH NO.	TEMP.	INTENSITY	FREQUENCY
1	.0006	.4240	1.2987	.30796E+08	6.
2	.6400	.4197	1.2974	.21987E+09	45.
3	1.2800	.4070	1.2934	.31172E+09	88.
4	1.9200	.3867	1.2869	.26523E+09	126.
5	2.5600	.3599	1.2777	.16353E+09	157.
6	3.2000	.3283	1.2660	.82295E+08	181.
7	3.8400	.2933	1.2520	.40375E+08	197.
8	4.4800	.2568	1.2359	.23900E+08	204.
9	5.1200	.2202	1.2182	.17821E+08	203.
10	5.7600	.1851	1.1994	.14079E+08	195.
11	6.4000	.1525	1.1799	.99452E+07	182.
12	7.0400	.1231	1.1604	.58110E+07	164.
13	7.6800	.0974	1.1414	.27496E+07	145.
14	8.3200	.0755	1.1232	.10540E+07	124.
15	8.9600	.0574	1.1061	.32955E+06	103.
16	9.6000	.0428	1.0904	.84690E+05	84.
17	10.2400	.0312	1.0763	.18014E+05	66.
X(19)=	4.6667	URI(19)= .42108E+17	FM(19)= .1815E+02	UAVG(19)= 244.56	UMAX(19)= 474.50
X(20)=	5.8796	URI(20)= .19497E+17	FM(20)= .2238E+02	UAVG(20)= 197.74	UMAX(20)= 375.14
X(21)=	7.4079	URI(21)= .23417E+16	FM(21)= .2746E+02	UAVG(21)= 160.31	UMAX(21)= 295.51
X(22)=	9.3333	URI(22)= .56788E+15	FM(22)= .3491E+02	UAVG(22)= 126.19	UMAX(22)= 232.49
X(23)=	11.7593	URI(23)= .10568E+15	FM(23)= .4246E+02	UAVG(23)= 102.85	UMAX(23)= 182.92
X(24)=	14.8157	URI(24)= .21549E+14	FM(24)= .5098E+02	UAVG(24)= 84.39	UMAX(24)= 144.02

\*\*\* SOUND PRESSURE LEVEL DIRECTIVITY \*\*\*

JET MACH NO. =	1.9662	JET DENSITY RATIO =	.4356
JET VELOCITY =	2199.16	JET EQUIV. DIAM. =	.0729

9.0 FT. ARC

ANGLE =	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0	PWL
FREQ.																
100	73.4	73.7	74.1	74.7	75.5	76.4	77.6	79.1	80.9	83.1	85.6	88.6	92.7	97.6	102.1	119.6
125	76.0	76.3	76.8	77.4	78.2	79.1	80.3	81.8	83.6	85.8	88.3	91.4	95.7	100.6	104.9	122.5
160	78.5	78.8	79.4	80.0	80.9	81.9	83.2	84.7	86.5	88.6	91.2	94.4	99.0	103.7	107.8	125.4
200	80.4	80.8	81.4	82.1	83.1	84.2	85.5	87.0	88.9	91.1	93.3	95.9	101.7	106.3	110.1	127.9
250	82.1	82.5	83.1	83.9	85.0	86.2	87.6	89.2	91.1	93.2	95.5	98.2	104.4	108.8	112.2	130.2
315	83.7	84.2	84.8	85.6	86.7	87.9	89.4	91.2	93.2	95.5	98.2	102.0	107.0	111.1	114.1	132.4
400	85.4	85.9	86.5	87.3	88.3	89.6	91.1	93.0	95.1	97.5	100.3	104.4	109.4	113.3	115.9	134.5
500	87.7	87.9	88.3	88.8	89.4	90.1	91.1	92.6	94.5	96.7	99.2	102.1	106.5	110.4	112.4	136.2
630	87.8	88.3	89.0	90.0	91.1	92.5	94.1	96.0	98.2	100.7	103.7	108.4	113.2	116.6	118.5	137.7
800	88.9	89.4	90.0	91.0	92.1	93.6	95.3	97.3	99.5	102.2	105.2	110.0	114.7	117.7	119.3	138.8
1000	90.9	90.4	91.0	91.8	93.0	94.4	96.2	98.1	100.7	103.4	106.5	111.3	115.6	118.3	119.5	139.5
1250	91.6	91.9	92.3	92.9	93.9	95.2	96.9	99.0	101.6	104.4	107.6	112.4	116.1	118.3	119.2	139.7
1600	93.9	94.1	94.3	94.7	95.2	96.2	97.6	99.7	102.2	105.2	108.7	113.4	116.4	117.9	118.2	139.7
2000	96.1	96.3	96.4	96.7	97.0	97.6	98.6	100.2	102.6	105.7	109.3	114.1	116.6	117.4	117.4	139.6
2500	98.1	98.3	98.5	98.8	99.1	99.5	100.0	101.1	103.0	105.9	109.8	114.5	116.8	117.3	117.3	139.9
3150	99.6	99.9	100.2	100.7	101.1	101.6	102.0	102.6	103.8	106.1	110.3	115.1	117.4	118.0	117.8	140.5
4000	100.5	100.9	101.4	102.0	102.8	103.5	104.1	104.8	106.2	108.6	111.0	116.0	118.6	119.2	118.4	141.6
5000	101.4	101.6	102.1	102.8	103.7	104.7	105.7	106.4	107.9	109.9	112.2	117.3	120.2	120.3	118.6	142.8
6300	103.6	103.3	103.2	103.5	104.3	105.4	106.7	107.9	109.7	112.3	115.9	119.0	121.8	121.1	118.4	144.1
8000	108.4	107.4	106.2	105.3	105.1	105.9	107.3	108.9	110.3	111.0	115.8	120.7	123.2	121.4	117.7	145.3
10000	114.5	113.2	111.4	109.3	107.5	106.8	107.6	109.3	111.2	112.4	117.2	122.0	124.1	121.2	116.7	146.4
12500	113.8	114.0	114.3	114.7	115.2	115.4	115.8	116.4	117.5	118.4	122.8	124.1	124.4	120.5	115.4	147.2
16000	112.5	112.7	113.0	113.4	114.0	114.7	115.2	115.7	116.5	117.4	123.0	124.1	124.1	119.2	113.8	147.3
20000	111.3	111.5	111.8	112.2	112.7	113.4	114.3	115.1	116.1	117.1	122.5	123.3	123.3	117.8	112.4	147.0
25000	110.0	110.2	110.5	110.9	111.4	112.1	113.0	114.2	115.2	116.2	121.5	122.0	122.0	116.3	111.2	146.4
31500	108.5	108.7	109.0	109.3	109.9	110.5	111.4	112.5	113.6	114.7	119.9	120.4	120.4	114.7	110.1	145.5
40000	106.7	106.9	107.2	107.6	108.1	108.7	109.5	110.6	111.8	113.0	117.7	118.3	118.3	112.9	108.9	144.3
50000	104.8	105.0	105.2	105.6	106.1	106.8	107.6	108.6	110.0	111.7	116.0	116.2	116.2	110.9	107.3	143.3
63000	102.3	102.5	102.8	103.2	103.7	104.3	105.1	106.1	107.5	108.9	112.0	112.0	113.6	108.0	105.0	142.0
80000	99.2	99.4	99.7	100.1	100.6	101.2	102.0	103.0	104.3	105.6	108.2	107.6	109.9	104.0	101.1	141.0
OVERALL	121.0	120.8	120.7	120.9	120.7	121.0	121.1	121.5	122.3	123.3	127.2	131.9	133.6	131.8	130.6	157.2
PWL	126.2	125.6	124.8	124.3	124.9	125.7	126.7	128.0	129.3	130.6	134.8	139.7	142.6	143.0	142.6	
PWLT	129.6	128.9	128.1	127.7	128.2	129.0	130.1	131.3	132.6	134.0	138.2	143.0	146.0	146.3	145.9	

## APPENDIX D

### PROGRAM SOURCE CODE LISTING

This appendix contains the FORTRAN IV source code listing for the aeroacoustic prediction model, suitable for running on the CDC 7600 computer. The listing of subroutines is in alphabetical order, as follows:

1. MAIN Program (MGB)
2. ARRCOS
3. ATMOS
4. CRD
5. ERF
6. LSPFIT
7. OUTPUT
9. PNLC
9. SHOCK
10. SLICE
11. TPNLC





45	NAMLIST/INPUT/	KX,NFST,LPHI,ISYM,NOV,CM,CH,GAM,CP,DTM,RU2M,	MGR	45
	IPS,X,DSIG,YE,ALPO,LFAY,NUM,KN,DALP,RA,PT,		MGR	46
	2TT,IQUIT,ALFA,AK,HK,ATOTAL,DEQ,NN,NUMANG,DIST,		MGR	47
	3NCASE,HF,NBREF,CMVC,CMVR,RMIN,NPRINT,STRFX,		MGR	48
	4STRFR,NCRDY,RCRDY,XCHDY,ALPHT,RETAIN,DELTA,		MGR	49
	5AMIN,FMIN,FMAX,ALPHMC,RETAMC,DS,NCFL		MGR	50
50			MGR	51
	INITIALIZE		MGR	52
	NN=0		MGR	53
	KX=15		MGR	54
	IQUIT=50		MGR	55
55	NPRINT=1		MGR	56
	LPHI=9999		MGR	57
	NCASE=1		MGR	58
	KNCAS=0		MGR	59
	NPAGE=0		MGR	60
60	NBREF=2		MGR	61
	FMIN=50		MGR	62
	FMAX=10000		MGR	63
	PI=3.1415927		MGR	64
65	PI2=6.2831853		MGR	65
	ROOT2=SQRT(2.)		MGR	66
	DTM=0.1		MGR	67
	RU2M=3.0		MGR	68
70	CM=0.075		MGR	69
	CH=1.150		MGR	70
	CMVR=0.25		MGR	71
	CMVC=0.08		MGR	72
	STRFX=1.259921		MGR	73
75	STRFR=.01		MGR	74
	ALPHMC=0.5		MGR	75
	RETAMC=0.325		MGR	76
	ALFA=1.0		MGR	77
80	AK =0.08		MGR	78
	RK =0.0		MGR	79
			MGR	80
			MGR	81
			MGR	82
			MGR	83
			MGR	84
			MGR	85
			MGR	86
			MGR	87
			MGR	88
			MGR	89
			MGR	90

90	IF(CP,LE,0.) CP=1716.0*GAM/(GAM-1.)	MGR	91
	WRITE(6,502)	MGR	92
	WRITE(6,504)KX,NEST,LPHI,JSYM,NPKINT,CN,CH,GAM,CP,	MGR	93
	1DTHN,RU2M,PS	MGR	94
95	IF(X(1),LE,0.0) X(1)=DEFQ(1)	MGR	95
	IF(DSIG(1),LE,0.0) DSIG(1)=STPR*X(1)	MGR	96
	DO 20 KA=2,KX	MGR	97
	IF(X(KA),LE,0.) X(KA)=STPR*X(KA-1)	MGR	98
	IF(DSIG(KA),LE,0.) DSIG(KA)=STPR*X(KA)	MGR	99
100	20 CONTINUE	MGR	100
	IF(NCRDY,LE,0) GO TO 15	MGR	101
	CALL LSPFIT(XCRDY,PCHDY,NCRDY,X,RMIN,KX,0. AAA)	MGR	102
	15 CONTINUE	MGR	103
	WRITE(6,506)	MGR	104
105	WRITE(6,508)(I,X(1),DSIG(I),RMIN(I),NOV(I),RETAIN(I),DELTA(I),	MGR	105
	IAM(ITN(I),I=1,KX)	MGR	106
		MGR	107
	GAMA=GAM-1.0	MGR	108
	PGC=CP*GAMA/GAM	MGR	109
110	LINE=30*KX	MGR	110
	M=1	MGR	111
	DO 100 K=2,NEST	MGR	112
	WRITE(6,510)K,XE(K),K,ALPO(K),K,LEAV(K),	MGR	113
	IK,NUM(K),K,KN(K)	MGR	114
115	NUMK=NUM(K)	MGR	115
	WRITE(6,512)(N,K,DALP(N,K),N,K,RA(N,K),N=1,NUMK)	MGR	116
	LINE=LINE+NUMK	MGR	117
	IF(LINF,LI,50) GO TO 100	MGR	118
	IF(K,GE,NEST) GO TO 110	MGR	119
120	NPAGE=NPAGE +1	MGR	120
	WRITE(6,500) NPAGE,KFICAS,(IDENT(N),N=1,R )	MGR	121
	LINE=4	MGR	122
	100 CONTINUE	MGR	123
125	DO 200 K=1,NEST	MGR	124
	ACH2=2.0*((PT(K )/PS)**(1.0-1.0/GAM)-1.0)/GAMA	MGR	125
	TE(K)=TT(K)/(1.0*.5*GAMA*ACH2)	MGR	126
	SV2 =GAM*PGC*TE(K)	MGR	127
	PUPF(K)=ACH2*GAM*PS	MGR	128
130	UE(K)=6.0	MGR	129
	FF(K)=0.0	MGR	130
	IF(ACH2,EQ,0.0) GO TO 200	MGR	131
	UE(K)=SOPT(ACH2*SV2)	MGR	132
	FF(K)=PU2E(K)*CP*(TT(K)-TT(1))/UE(K)	MGR	133
		MGR	134
		MGR	135

```

135 IF (ACH2.GT.0.0) GO TO 200
136 WRITE(6,516) ACH2
137 STOP
138
139 200 ACH(K)=SORT(ACH2)
140 IIRFF=UE(NHREF)
141 RU2REF=RU2F(NHREF)
142 FIRSTU=UE(1)
143 SUF=UREF
144 TAA=TF(1)
145 PAA=PS
146 RHOE=PAA/(1716.0*TAA)
147 CO=SORT(1716.0*GAM*TAA)
148 AO=CO
149 AL=RHOE*(SUF/CO)**5*SUF**3*ATOTAL
150 ASP=PS*GAM*GAM*PGC*SORT(GAM*PGC*TE(1))*TE(1)
151 RJET=TAA/TE(NHREF)
152 DIA=DEQ(1)
153 DIJET=DIA
154 UJET=SUE-FIPSTU
155 EMACH=UJET/CO
156 INITS=474.8*474.8*.25E9*RHOE*CO
157
158 WRITE EXIT CONDITIONS
159
160 C
161 C
162 C
163 NPAGE=NPAGE +1
164 WRITE(6,500) NPAGE,KNCAS,(IDENT(K),K=1,8)
165 WRITE(6,518)
166 WRITE(6,520)(K,PI(K),TT(K),TE(K),UE(K),ACH(K),RUPE(K),EF(K),
167 IK=1,NEST)
168 WRITE(6,540) NHREF
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170 C
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172 C
173 WRITE ADDITIONAL INPUT
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[illegible]

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INITIALIZATION AND HOUNDARY INTEGRATION ( K = INDEX ON HOUNDARY )

```

DO 1100 K=2,NEST
  NODI=2
  SIC=0.0
  SIR=0.0
  SIX=0.0
  VI=0.0
  TI=0.0
  NUMK=NUM(K)
  LEAF=LFAV(K)
  KNK=KN(K)
  IMH=1
  IF (X(KA).LE.XE(K)) GO TO 1100
  IF ((UE(K).EQ.0.0).AND.(UE(KNK).EQ.0.0)) GO TO 1100
  VMAX=AMAX1(UE(K),UE(KNK))
  VMIN=AMIN1(UE(K),UE(KNK))
  VR=VMIN/VMAX
  CVR=1./((1.+CVR*VF)
  CMC=1.+CMC*ACH(K)
  DRDX=CM*CVR/CMC
  DRDX=CH*DRDX
  IF (DRDX.EQ.DRDX) IMH=2
  CMX=DRDX*(X(KA)-XE(K))
  CHX=DRDX*(X(KA)-XE(K))
  PHAL=PHI-ALPO(K)
  ARPA=ABS(PHAL)
560  IF (ARPA.LE.PI) GO TO 575
  PHAL=PHAL-SIGN(PI2,PHAL)
  GO TO 560
C
575  COSPA=COS(ARPA)
  DELSIG=SIG
  NELRA=RA(NUMK,K)
  IF (NCRDY.LE.0) GO TO 605
  CALL LSPFIT(XCRDY,RCHDY,NCRDY,XE(K),RMINEX,1,0,AAA)
  RMNSOE=RMINEX*PMINEX
  SIGSO=SIG*SIG
  RMINSO=RMIN(KA)*RMIN(KA)
  RASO=RA(NUMK,K)*RA(NUMK,K)
  DELSIG=SQRT(SIGSO-RMINSO)
  NELRA=SQRT(PASO-RMNSOE)
605  CONTINUE

```

275	C	RAD0=SQRT((DELPA-DELSIG)*(DELPA-DELSIG) 1+2.0*DELPA*DELSIG*(1.0-COSPA))	MGR	276
		IF (RAD0.GT.(.0005*DELSIG)) GO TO 600	MGR	277
280		MODE=1	MGR	278
		GO TO 650	MGR	279
	C	600 COST0=(DELSIG-DELPA*(COSPA)/RAD0	MGR	280
		IF (ARS(COST0).LT.1.0) GO TO 610	MGR	281
285		TH0=(PI-SIGN(PI,COST0))/2.0	MGR	282
		SINT0=0.0	MGR	283
		GO TO 620	MGR	284
	C	610 SINT0=SIGN(SQRT(1.0-COST0*COST0),PHAL)	MGR	285
		TH0=PI-SIGN(PI-ARCCOS(COST0),PHAL)	MGR	286
290	C	620 RADX=RAD0/CHX	MGR	287
		POWER=RADX*RADX	MGR	288
		IF (POWER.GT.25.0) GO TO 625	MGR	289
295		VA0=1.0-EXP(-POWER)	MGR	290
		GO TO (630+640).IMH	MGR	291
		630 TAO=1.0-EXP(-(RAD0/CHX)*(RAD0/CHX))	MGR	292
		640 SA=DRDX*(C.88623*ERF(RADX)+RADX*(VA0-1.0))	MGR	293
		SAP0=SA*COST0	MGR	294
		SAC0=SA*SINT0	MGR	295
300		SAX0=((DRDX*RADX)**2)*(1.-VA0)	MGR	296
		GO TO 635	MGR	297
		625 CONTINUE	MGR	298
		VA0=1.0	MGR	299
305		TA0=1.0	MGR	300
		SA=0.88623*DRDX	MGR	301
		SAP0=SA*COST0	MGR	302
		SAC0=SA*SINT0	MGR	303
		SAX0=0.0	MGR	304
		635 CONTINUE	MGR	305
310	C	LEAF INTEGRATION:	MGR	306
	C	J = LEAF NUMBER OF BOUNDARY K	MGR	307
	C	N = POINT NUMBER OF BOUNDARY K	MGR	308
315	C	650 DO 1000 J=1,LEAF	MGR	309
		DO 1000 N=1,NUMK	MGR	310
		PHAL=PHAL-DALP(N,K)	MGR	311
		ALPA=ARCS(PHAL)	MGR	312
		IF (ALPA.LE.PI) GO TO 670	MGR	313
320		PHAL=PHAL-SIGN(PI2,PHAL)	MGR	314
		GO TO 660	MGR	315
	C	670 COSPA=COS(ALPA)	MGR	316
		DELPA=PA(1,K)	MGR	317
			MGR	318
			MGR	319
			MGR	320
			MGR	321
			MGR	322
			MGR	323
			MGR	324
			MGR	325

325	IF (NCRDY.GT.0) DELPA=SQRT(PA(H,K)*PA(N,K)-DMNSQF)	MGR	326
	PAD =SQRT((DELPA-DELSIG)*(DELPA-DELSIG)	MGR	327
	1+2.0*DELPA*DELSIG*(1.0-COSPA))	MGR	328
	IF (PAD.GT.(.0005*DELSIG)) GO TO 680	MGR	329
	NODE=1	MGR	330
330	GO TO 900	MGR	331
		MGR	332
		MGR	333
		MGR	334
335	680 COST=(DELSIG-DELPA*CUSPA)/RAD	MGR	335
	IF (ARS(COST).LT.1.0)GO TO 690	MGR	336
	TH=(PI-SIGN(PI,COST))/2.0	MGR	337
	SINT=.0	MGR	338
	GO TO 710	MGR	339
		MGR	340
		MGR	341
340	710 NODE=2	MGR	342
	OTH=C.0	MGR	343
	GO TO 800	MGR	344
		MGR	345
345	710 DTH=TH-THO	MGR	346
	ARDTH=ARS(DTH)	MGR	347
	IF (ARDTH.LE.DTH) GO TO 800	MGR	348
	IF (ARDTH.LE.PI)GO TO 710	MGR	349
		MGR	350
350	C CORPECTION=-0-360	MGR	351
		MGR	352
		MGR	353
		MGR	354
355	720 THO=THO+SIGN(PI2,DTH)	MGR	355
	GO TO 710	MGR	356
		MGR	357
		MGR	358
		MGR	359
		MGR	360
360	PCRC=PCRC+SIGN(.0000001,PCRC)	MGR	361
	ABLE=(RADO*SINTO-RAD*SINT)/PCRC	MGR	362
	RKP=RADO*SINTO-ARLF*RADN*COSTO	MGR	363
		MGR	364
365	AUXILIARY INTEGRATION	MGR	365
		MGR	366
		MGR	367
		MGR	368
		MGR	369
		MGR	370

379	SINT=SIN(TH)	MGB	371
	RAD=8KR/(SINT-AHLE*COST)	MGR	372
	RADX=PAD/CMX	MGB	373
	POWER=RADX*RADX	MGB	374
375	IF (POWER.GT.25.0) GO TO 725	MGR	375
	VA =1.0-EXP(-POWER)	MGB	376
	SA=DRDX*(0.88623*ERF(RADX)+RADX*(VA-1.0))	MGB	377
	SAR=SA*COST	MGB	378
	SAC=SA*SINT	MGB	379
380	SAX=((DRDX*RADX)**2)*(1.-VA)	MGR	380
	GO TO 735	MGR	381
	725 CONTINUE	MGR	382
	VA=1.0	MGB	383
	TA=1.0	MGB	384
	SA=0.88623*DRDX	MGB	385
385	SAR=SA*COST	MGR	386
	SAC=SA*SINT	MGR	387
	SAX=0.0	MGR	388
	735 CONTINUE	MGB	389
	VI=VI+(VA+VA0)*DTH	MGB	390
390	SIR=SIR+(SAR+SAR0)*DTH	MGB	391
	SIC=SIC+(SAC+SAC0)*DTH	MGB	392
	SIX=SIX+(SAX+SAX0)*DTH	MGB	393
	GO TO (740,750),IMH	MGB	394
	C	MGR	395
395	740 CONTINUE	MGR	396
	IF (POWER.GT.25.0) GO TO 745	MGR	397
	TA=-EXP(-(PAD/CHX)*(RAD/CHX))+1.0	MGR	398
	745 CONTINUE	MGR	399
400	TI=TI+(TA+TA0)*DTH	MGR	400
	TA0=TA	MGB	401
	C	MGR	402
	750 VA0=VA	MGR	403
	SAC0=SAC	MGR	404
405	SAP0=SAR	MGB	405
	SAX0=SAX	MGR	406
	TH0=TH	MGR	407
	790 CONTINUE	MGR	408
	GO TO 900	MGB	409
410	C	MGR	410
	C	MGB	411
	MAIN LINE INTEGRATION	MGB	412
	C	MGR	413
	800 RADX=RAD/CMX	MGR	414
	POWER=RADX*RADX	MGB	415
	IF (POWER.GT.25.0) GO TO 825		



415	VA = 1.0-EXP(-POWER)	MGB	416
	SA=URDX*(0.88623*ERF(MADX)+RADX*(VA-1.0))	MGB	417
	SAR=SA*COST	MGB	418
	SAC=SA*SINT	MGB	419
420	SAX=((ORDX*RADX)**2)*(1.-VA)	MGB	420
	GO TO R35	MGB	421
	R25 CONTINUE	MGB	422
	VA=1.0	MGB	423
	TA=1.0	MGB	424
425	SA=0.88623*DRDX	MGB	425
	SAR=SA*COST	MGB	426
	SAC=SA*SINT	MGB	427
	SAX=0.0	MGB	428
	R35 CONTINUE	MGB	429
	VI=VI+(VA+VAO)*DTH	MGB	430
430	SIR=SIR+(SAR+SAR0)*DTH	MGB	431
	SIC=SIC+(SAC+SAC0)*DTH	MGB	432
	SIX=SIX+(SAX+SAX0)*DTH	MGB	433
	GO TO (R10+R20)*IMH	MGB	434
	C	MGB	435
435	R10 CONTINUE	MGB	436
	IF (POWER.GT.25.0) GO TO R45	MGB	437
	TA=-EXP(-(RAD/CHX)*(RAD/CHX))+1.0	MGB	438
	R45 CONTINUE	MGB	439
	TI=TI+(TA+TA0)*DTH	MGB	440
440	TAO=TA	MGB	441
	C	MGB	442
	R20 VAO=VA	MGB	443
	SAC0=SAC	MGB	444
	SAP0=SAR	MGB	445
445	SAX0=SAX	MGB	446
	TH0=TH	MGB	447
	R60 RAD0=RAD	MGB	448
	COST0=COST	MGB	449
	SINT0=SINT	MGB	450
450	GO TO (1020+1010)*IMH	MGB	451
	C	MGB	452
	C	MGB	453
	C	MGB	454
	NEST SUMMATIONS	MGB	455
455	GO TO (1020+1010)*IMH	MGB	456
	1010 TI=VI	MGB	457
	1020 CONTINUE	MGB	458
	C	MGB	459
	1050 UGLY=.07957747*(RU2E(K)-RU2E(KNK))	MGB	460
	EFE =.07957747*(EF(K)-EF(KNK))*TI+EFE	MGB	461
460	RU2=UGLY*VI+RU2	MGB	462
	UGLY=.07957747*(UE(K)**2-UE(KNK)**2)	MGB	

```

465      STC=UGLY*STC*STC
      STR=UGLY*SIR*STR
      STX=10.0*UGLY*SI*STX
      1110 CONTINUE
      C
      C      FINAL CALCULATIONS
      C
      C      IF (RU2.GT.0.0) GO TO 1110
      C
      U=0.0
      RHO=RHOE
      T=TT(1)
      UND=0.0
      TUPBIN=0.0
      RU2=0.0
      RU=0.0
      TAU=0.0
      DU=0.0
      IIM=0.0
      EFE=0.0
      IF (NPRINT.LE.0) GO TO 1116
      IF (NPP.LT.NPRINT) GO TO 1116
      GO TO 1117
      C
      1110 RMP=RU2*PGC/PS
      UAP=SQRT(RMP*TT(1))
      RM=RMP/(2.0*CP)
      HM=EFF*RM/(UAP*RU2)
      PSI=RU2/2.0*CP*PS/PGC
      HPSI=EFE/(2.0*PSI)
      U=HPSI*SQRT(HPSI**2*RU2*CP*TT(1)/PSI)
      IF (U.GT.UMAX(KA)) UMAX(KA)=U
      C
      1113 T=U*U/RMP
      TAU=SQRT(STR*STR + DELTA*STC*STC + BETA*STX*STX)
      ACHW=U/SQRT(GAM*PGC*T)
      RU=RU2/U
      RHO=RHI/U
      C
      500 UH=TAU**3.5
      DU=SQRT(STR*STR*AMULT*STC*STC)
      C
      IF (NPRINT.LE.0) GO TO 1116
      IF (NPP.LT.NPRINT) GO TO 1116
      UND=U/UREF
      TURBIN=SQRT(TAU)/UREF
      1117 CONTINUE
      RND=SIG/DIA
      1115 LINE=LINE+1
      IF (LINE.LE.55) GO TO 1120
      IPAGE=NPAGE +1
      WRITE(6,500) NPAGE,K,I,CAS,(IDENT(K),K=1,8)

```

515	WRITE(6,534) X(KA),XND	MGR	515
	LINF=R	MGR	516
516	1120 CONTINUE	MGR	517
	WRITE(6,536) M,SIG,PHID,U,PHO,T,UND,TUPRIN,PND	MGR	518
517	1116 CONTINUE	MGR	519
	IF(1.GT.1)GO TO 1130	MGR	520
520	C	MGR	521
	TSTH=RU2-RU2E(1)	MGR	522
521	TSTL=TSTH	MGR	523
	GO TO 1140	MGR	524
524	1130 TSTH=MAX1(TSTH,(RU2-RU2E(1)))	MGR	525
	TSTL=MIN1(TSTL,(RU2-RU2E(1)))	MGR	526
525	IF(1.NE.ISSY)GO TO 1145	MGR	527
	1140 IF(1SYN.EQ.1)GO TO 1145	MGR	528
528	C	MGR	529
	SUR=SRU+UR/2.0	MGR	530
530	SRU=SRU+RU/2.0	MGR	531
	SRUP=SRU2+RU2/2.0	MGR	532
531	SDU=SDU+DU/2.0	MGR	533
	SEFE=SEFE+EFE/2.0	MGR	534
534	GO TO 1150	MGR	535
535	C	MGR	536
	1145 CONTINUE	MGR	537
	SRU=SRU+RU	MGR	538
538	SUR=SRU+UR	MGR	539
	SRU2=SRU2+RU2	MGR	540
540	SDU=SDU+DU	MGR	541
	SEFE=SEFE+EFE	MGR	542
542	1150 CONTINUE	MGR	543
543	C	MGR	544
	PHI=PHI+DPHI	MGR	545
545	1200 CONTINUE	MGR	546
	FIS=IS	MGR	547
547	TSTD=MAX1(TSTD,ABS(TSTH-TSTL))	MGR	548
	SJAM=SRU/FIS+SIG+SRM	MGR	549
549	SRUM=SRU/FIS+SIG+SRUM	MGR	550
	SRU2M=SRU2/FIS+SIG+SRU2M	MGR	551
551	TAP(M)=(SUR/FIS)**0.2857143	MGR	552
	DUDR(M)=SDU/FIS	MGR	553
553	IF(SRU.LE.0.0) GO TO 1210	MGR	554
	IF(SRU2.LE.0.0) GO TO 1210	MGR	555
555	UR(M)=SRU2/SRU	MGR	556
	HR=SEFE/SRU	MGR	557
557	TTP=HTR/CP+TT(1)	MGR	558
	TSR=TTP-0.5*UP(M)*UR(M)/CP	MGR	559
559	RHOR(M)=PS/(PGC*TSR)	MGR	560

560	GO TO 1220	MGR	561
	1210 CONTINUE	MGR	562
	UP(M)=0.0	MGR	563
	PHOR(M)=PHOE	MGR	564
	TAUR(M)=0.0	MGR	565
565	NUD2(M)=0.0	MGR	566
	1220 CONTINUE	MGR	567
	SIGR(M)=SIG	MGR	568
	TSTHL=AMAX1(TSTHL,AHS(TSTH),AHS(TSTL))	MGR	569
	IF(M,LE,NOV(KA)) GO TO 1260	MGR	570
570	IF(TSTHL,LE,PU2M)GO TO 1510	MGR	571
	1260 SIG=SIG+DSIG(KA)-RUG	MGR	572
	RUG=0.0	MGR	573
	1500 CONTINUE	MGR	574
	1510 IF(TSTD,GT,2.0*RU2M)GO TO 1600	MGR	575
575	IT=2	MGR	576
	IS=1	MGR	577
	IF(TSTD,GT,PU2M)GO TO 1600	MGR	578
	ISYM=1	MGR	579
	1600 CONTINUE	MGR	580
580	C	MGR	581
	C	MGR	582
	CALL LSPFIT(SIGR,RHOR,M,SIGR,DRDP,M,1,020002)	MGR	583
	CMX=CM*X(KA)	MGR	584
585	DO 1605 IR=1,M	MGR	585
	IF(UP(IR),LE,0.0) GO TO 1605	MGR	586
	NUDR(IR)=NUDR(IR)/(UP(IR)*CM*CMX)	MGR	587
	1605 CONTINUE	MGR	588
	FM(KA)=PI2*SRUM*DSIG(KA)*32.17405	MGR	589
	HAVG(KA)=SPU2M/SRUM	MGR	590
590	URI(KA)=PI2*SUM*DSIG(KA)*UMAX(KA)/X(KA)	MGR	591
	IF(NN,EQ,4) GO TO 1800	MGR	592
	CALL SLICE(X(KA),DSIG(KA),DX,M)	MGR	593
	1800 CONTINUE	MGR	594
	WRITE(6,524)	MGR	595
595	WRITE(6,526) KA,X(KA),KA,URI(KA),KA,FM(KA),KA,HAVG(KA),KA,UMAX(KA)	MGR	596
	IF(NPR,GE,NPRINT) NPP=0	MGR	597
	2000 CONTINUE	MGR	598
	C	MGR	599
	C	MGR	600
600	IF(NN,EQ,4) GO TO 4000	MGR	601
	CALL OUTPUT(FMACH,OBJT,PJFT,UJET,UNITS)	MGR	602
	4000 CONTINUE	MGR	603
	IF(KNCAS,LT,NCASE) GO TO 1	MGR	604
	STOP	MGR	605
605	C	MGR	606
	C	MGR	607
	FORMAT SECTION	MGR	

```

610 510 FORMAT(1H1,10X,21H* * * M G R * * *20X,4HPAGE141///5X,61HCOMPU
      1TATION OF AERO-Acoustic PROPERTIES OF SUPPRESSOR NOZZLES///2X,
      2HRCASF NO.15,5X,RA10//)
615 502 FORMAT(1H0,40X,10HINPUT DATA//)
      115,12H ISYM=12,14H NX=13,13H NPRINT=13, 11H CM=F6.3// LPHI=
      2 3M=F7.4,10H CH=F6.3,9H RI2M=F7.4,8H PS=F7.1// DTH
      506 FORMAT(1H0,15X,82HCOMPUTATION MESH CONTROL PARAMETRS.....
      1.....// TURBULENCE CONSTANTS//15X,9HSLICE NO.,5X,1HX,14X,
      24HNSIG,11X,4HMIN,09X,3HNOV,6X,4HBETA,5X,SHDELTA,6X,2HNU//)
620 508 FORMAT(120,3F15.5,110,3F10.2)
      1(12,2H)=F7.4, 7H LFAV(12,2H)=I3, 7H NUM(12,2H)=I3,7H ALPO
      22,2H)=I3)
625 512 FORMAT(23H0
      112,2H)=F7.4,7H DALP(12,1H,12,2H)=F7.4,7H RA(12,1H,
      516 FOPMAT(//80H*** ERROR - MACH NO. SQUARE IS NOT GREATER THAN ZERO
      1- CASE WILL TERMINATE ***))
630 518 FORMAT(1H0,35X,15HEXIT CONDITIONS//3X,4HCON=,2X,5HTOTAL,6X,5HTOTAL
      1,5X,4HSTATIC,2X,4HVELOCITY,5X,4HMACH,5X,4HRMOMENTUM,6X,4HENTHALPY/
      23X,4HTOUR,2X,4HMPRESS,5X,5HTEMP,5X,5HTFMP,4X,5H(FPS),6X,6HNUMBER
      3,6X,4HFLUX,10X,4HFLUX/9X,5H(PSF),5X,7H(DEG K),3X,7H(DEG R),23X,
      410H(LR/SO-FT),4X,10H(LR/SO-FT)//)
635 520 FORMAT(16,4F10.2,F10.4,2E14.5)
      15X,4HAK =E12.5,5X,4HRK =E12.5// 6X,7HTOTAL=F 9.5,5X,6HDEQ =F10.5
      2, 5X,6HIQUT=15, 5X,4HNN =13, 5X,6HUREF =F10.2)
640 524 FORMAT(1H )
      526 FORMAT(3H X(12,2H)=F9.4,6H URI(12,2H)=E11.5,5H FM(12,2H)=E10.4,
      17H UAVG(12,2H)=F8.2,7H UMAX(12,2H)=F8.2)
      528 FORMAT(6E12.5)
      534 FORMAT(17H AXIAL LOCATION =F10.5,11H (X/DEG = F10.5,1H)//
      13X,1HM,5X,1HR,7X,5HANGLE,5X,1HU,7X,7HDENSITY,6X,5HTEMP,3X,6HU/UREF
      2,2X,9HTURB.INT,2X,5HR/DEQ//)
645 536 FORMAT(14,F10.5,F8.2,F9.2,F12.7,F10.2,3F9.5)
      540 FORMAT(1H0,12HROUNDUP NO. 105,39H HAS BEEN DESIGNATED AS THE R
      1REFERENCE//)
      542 FORMAT(1H0, 5X,5HCMC=F11.6,05X,5HCMVR=F11.6//)
      548 FORMAT(1H0, 5X,6HSTRF=F10.5,5X,6HSTRFR=F10.5 )
      550 FORMAT(1H0,5X,7HALPHMC=F9.4,5X,7HBETAMC=F9.4)
      552 FORMAT(1H1)
      554 FOPMAT(RA10)
650 END

```

FUNCTION ARCCOS	76/76	OPT=1	FTN 4.5+410	10/10/77	14.30.05\$
1	CARCCOS	ARC COSINE (PRINCIPAL VALUE)		ARCCOS	2
	FUNCTION ARCCOS(X)			ARCCOS	3
	IF(X.GT.0.6) GO TO 5			ARCCOS	4
	IF(X.LT.0.0) GO TO 10			ARCCOS	5
5	ARCCOS = 1.5707963			ARCCOS	6
	GO TO 15			ARCCOS	7
	5 ARCCOS = ATAN(SQRT(1.-X**2)/X)			ARCCOS	8
	GO TO 15			ARCCOS	9
10	10 ARCCOS = ATAN(SQRT(1.-X**2)/X)+3.1415927			ARCCOS	10
	15 RETURN			ARCCOS	11
	END			ARCCOS	12

SUBROUTINE ATMOS	76/76	OPT=1	FTN 4.5+410	10/10/77	14.30.05\$
1	C	ATMOSPHERIC ATTENUATION SUBROUTINE		ATMOS	2
	C			ATMOS	3
	C			ATMOS	4
5	C	ATMOSPHERIC AIR ATTENUATION CORRECTIONS FOR STANDARD DAY		ATMOS	5
	C	(59 DEG. F AND 70 PCT. REL. HUM.) FROM SAE ARP 866 (1964)		ATMOS	6
	C	ARE ADDED TO LOSSLESS SPECTRA		ATMOS	7
	C			ATMOS	8
	C			ATMOS	9
10	C	SUBROUTINE ATMOS(SPL,RADIUS)		ATMOS	10
	C			ATMOS	11
	C			ATMOS	12
				ATMOS	13
15		DIMENSION SPL(19,34),RADIUS(19),AA(34)		ATMOS	14
		DATA AA/.07,.09,.11,.14,.18,.23,.29,.36,.45,.58,.72,.92,		ATMOS	15
		11.17,1.47,1.85,2.39,3.03,3.97,5.47,7.73,9.03,12.87,18.76,26.97,		ATMOS	16
		238.98,58.67,84.58,121.56,175.77,256.39,363.19,519.95,752.16,		ATMOS	17
		31015.82/		ATMOS	18
	C			ATMOS	19
	C			ATMOS	20
20		DO 1 I=1,19		ATMOS	21
		DO 1 J=1,34		ATMOS	22
		IF(SPL(I,J).LE.0.0) GO TO 1		ATMOS	23
		SPL(I,J)=SPL(I,J)-RADIUS(I)*AA(J)/1000.0		ATMOS	24
	1	CONTINUE		ATMOS	25
25		RETURN		ATMOS	26
		END			

SURROUTINE CRD	76/76	OPT=1	FTN 4.5*410	10/10/77	14.30.055
1	*			CRD	2
	*			CRD	3
				CRD	4
5			COMMON/SHLD/ G2(200),RIN(200),MACH(200),TEMP(200),RSIG(19,5), 1TERM(200),SHIELD(200),MCIN(200),THE,CT,NTP,NP,ALPHT(19),ITH REAL MACH,MCIN,MC,KIN,K,M0	CRD	5
	*			CRD	6
	*			CRD	7
	*			CRD	8
	*			CRD	9
10	*		CALCULATION OF DIRECTIVITY	CRD	10
				CRD	11
			PI=3.1415926	CRD	12
			PI02=PI/2.	CRD	13
			DO 11 IR=1,NR	CRD	14
			R0=RIN/(R)	CRD	15
			MC=MCIN(IR)	CRD	16
15			SHIELD(IP)=0.0	CRD	17
	*****			CRD	18
	*****		IF (THE.GT.PI02 ) GO TO 260	CRD	19
20	*			CRD	20
	*			CRD	21
	*		FINDING RELATIONSHIP BETWEEN R0 AND TURNING PTS.	CRD	22
				CRD	23
			IF (NTP.EQ.0) GO TO 260	CRD	24
			IF (NTP.EQ.1) GO TO 230	CRD	25
25			IF (NTP.EQ.2) GO TO 250	CRD	26
			RSIG(ITH,1)=RSIG(ITH,NTP-1)	CRD	27
			PSIG(ITH,2)=RSIG(ITH,NTP)	CRD	28
			NTP=2	CRD	29
			GO TO 250	CRD	30
30	230		CONTINUE	CRD	31
	*			CRD	32
	*		ONE TURNING POINT	CRD	33
	*			CRD	34
			RSIG1=RSIG(ITH,1)	CRD	35
35			IF (P0.GE.RSIG1) GO TO 260	CRD	36
			R1=R0	CRD	37
			R2=RSIG1	CRD	38
			GO TO 261	CRD	39
			CONTINUE	CRD	40
40	250			CRD	41
	*		TWO TURNING POINTS	CRD	42
	*			CRD	43
	*		RSIG1=RSIG(ITH,1)	CRD	44
			RSIG2=RSIG(ITH,2)	CRD	45

45	IF(RC.GE.RSIG2) GO TO 260	CRD	46
	IF(RC.LE.RSIG1) GO TO 262	CRD	47
	R1=R0	CRD	48
	R2=RSIG2	CRD	49
50	GO TO 261	CRD	50
	CONTINUE	CRD	51
	R1=RSIG1	CRD	52
	R2=RSIG2	CRD	53
	CONTINUE	CRD	54
55	* CALCULATION OF EXP. SHIELDING	CRD	55
	* FINDING INTERVAL INTO WHICH R1 AND R2 FALL	CRD	56
	* DO 265 J=1,NR	CRD	57
	IF(RIN(J).GT.R1) GO TO 266	CRD	58
60	CONTINUE	CRD	59
	CONTINUE	CRD	60
	J1=J	CRD	61
	J11=J1-1	CRD	62
65	DO 267 J=1,NR	CRD	63
	IF(RIN(J).GT.R2) GO TO 268	CRD	64
	CONTINUE	CRD	65
	CONTINUE	CRD	66
	J2=J	CRD	67
70	J21=J2-1	CRD	68
	EVALUATION OF INTEGRAL OF G	CRD	69
	* IF(J1.EQ.J2) GO TO 269	CRD	70
	* IF(J1.EQ.J21) GO TO 270	CRD	71
	* J211=J21-1	CRD	72
	* SUM=0.	CRD	73
75	DO 281 J=J1,J211	CRD	74
	GM=.5*(SORT(ARS(G2(J)))+SORT(ARS(G2(J+1))))	CRD	75
	SUM=SUM+GM*(RIN(J+1)-RIN(J))	CRD	76
80	CONTINUE	CRD	77
	GO TO 284	CRD	78
	CONTINUE	CRD	79
85	J1=J2	CRD	80
	SGN1=1.	CRD	81
	SGN2=1.	CRD	82
	IF(G2(J1).LT.0.) SGN1=-1.	CRD	83
	IF(G2(J1).LT.0.) SGN2=-1.	CRD	84
90	SG1=SORT(ABS(G2(J1)))*SGN1	CRD	85
	SG2=SORT(ABS(G2(J1)))*SGN2	CRD	86
		CRD	87
		CRD	88
		CRD	89
		CRD	90
		CRD	91
		CRD	92
		CRD	93



95		SLOPE=(SG2-SG1)/(RIN(J1)-RIN(J11))	94
		SUM=SG1*R2+SLOPE*(.5*R2**2-RIN(J11)*R2)	95
		A-SG1*R1-SLOPE*(.5*R1**2-RIN(J11)*R1)	96
		SUM=-SUM	97
	273	GO TO 280	98
		CONTINUE	99
100	284	SUM=0.	100
	*	CONTINUE	101
	*		102
	*	CALCULATION OF END CONTRIBUIONS	103
			104
105		SGN1=1.	105
		SGN2=1.	106
		IF (G2(J11).LT.0.) SGN1=-1.	107
		IF (G2(J1).LT.0.) SGN2=-1.	108
		SG1=SQRT(ABS(G2(J11)))*SGN1	109
		SG2=SQRT(ABS(G2(J1)))*SGN2	110
110		SLOPE=(SG2-SG1)/(RIN(J1)-RIN(J11))	111
		SUM1=SG1*RIN(J1)+SLOPE*(.5*RIN(J1)**2	112
		A-RIN(J11)*RIN(J1)-SG1*R1	113
		A-SLOPE*(.5*R1**2-RIN(J11)*R1)	114
		SUM1=-SUM1	115
115		SGN1=1.	116
		SGN2=1.	117
		IF (G2(J21).LT.0.) SGN1=-1.	118
		IF (G2(J2).LT.0.) SGN2=-1.	119
		SG1=SQRT(ABS(G2(J21)))*SGN1	120
120		SG2=SQRT(ABS(G2(J2)))*SGN2	121
		SLOPE=(SG2-SG1)/(RIN(J2)-RIN(J21))	122
		SUM2=SG1*R2+SLOPE*(.5*R2**2	123
		A-RIN(J21)*R2-SG1*RIN(J21)	124
		A-SLOPE*(.5*RIN(J21)**2-RIN(J21)*RIN(J21))	125
125		SUM2=-SUM2	126
		SUM=SUM1+SUM2+SUM	127
	280	CONTINUE	128
		SHIELD(IR)=SUM	129
130	261	CONTINUE	130
	*		131
	*	CALCULATION OF UNSHIELDED SOLUTION	132
	*		133
		G050=ARS(G2(IR))	134
135		IF (G2(IR).LT.0.0) G050=0.0	135
		T0=TEMP(IR)	136
		TEMP(IR)=(CT*CT+G050)**2/T0	137
	79	CONTINUE	138
	11	RETURN	139
140		END	140
			141

FUNCTION ERF 76/76 OPT=1 FTN 4.5+410 10/10/77 14.30.05\$

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1  CRRF      ERROR FUNCTION APPROXIMATION
      FUNCTION ERF(X)
      SIGN=1.0
      IF(X.LT.0.0) SIGN=-1.0
      IF(ABS(X).GT.5.0) GO TO 50
      T=1.0/(1.0+0.47047*ABS(X))
      ERF=1.0-((0.3486242*T-0.095479H*T*T+0.7478556*T*T*T)*EXP(-X*X))
      ERF=ERF*SIGN
100 RETURN
50 ERF=SIGN
   GO TO 100
   END

```

ERF 2  
ERF 3  
ERF 4  
ERF 5  
ERF 6  
ERF 7  
ERF 8  
ERF 9  
ERF 10  
ERF 11  
ERF 12  
ERF 13

SUBROUTINE LSPFIT 76/76 OPT=1 FTN 4.5+410 10/10/77 14.30.05\$

```

1  *LSPFIT  INTEGRATE OR INTERPOLATE
C
C  INTEGRATE OR INTERPOLATE USING A PARABOLA WHICH PASSED THROUGH THE
C  AND (I+1) POINTS BUT MISSES THE (I-1) AND (I+2) POINTS (IF THEY DO
C  EXIST) SUCH THAT THE SQUARE OF THE DEVIATION IS A MINIMUM. NOTE
C  THAT I IS GENERALLY SELECTED SUCH THAT
C      X(I).LE.XC.LT.X(I+1)
C  THE EQUATION FOR THE PARABOLA IS
C      Y-Y(I) = R*(X-X(I)) + C*(X-X(I))**2
C
10  SURROUTINE LSPFIT(X,Y,NPTS,XC,YC,NXC,ND,AAA)
      DIMENSION AAA(1:10)
      DIMENSION X(10),Y(10),XC(10),YC(10)
      NOTE. THE DIMENSION #10# DOES NOT NEED TO AGREE WITH THE CALLING
C
15  INPUT-
C  X,Y  PTS. ON CURVE
C  NPTS NO. OF X
C  XC   LIST OF X AT WHICH CALC TO BE DONE
C  YC(I) INTEGRATION CONSTANT IF ND=-1
C  NXC  NO. OF XC
C  ND   =0 TO GET COORD. =1 TO GET 1ST DERIVATIVE.
C      =-1 FOR INTEGRATION
C
      LSPFIT 2
      LSPFIT 3
      LSPFIT 4
      LSPFIT 5
      LSPFIT 6
      LSPFIT 7
      LSPFIT 8
      LSPFIT 9
      LSPFIT 10
      LSPFIT 11
      LSPFIT 12
      LSPFIT 13
      LSPFIT 14
      LSPFIT 15
      LSPFIT 16
      LSPFIT 17
      LSPFIT 18
      LSPFIT 19
      LSPFIT 20
      LSPFIT 21
      LSPFIT 22
      LSPFIT 23
      LSPFIT 24
      LSPFIT 25

```

25	C	OUTPUT				LSPFIT	26
	C	YC	COORDINATE OR DERIVATIVE AT XC	OR		LSPFIT	27
	C		YC(IC)= INTEGRAL(Y*DX) FROM XC(1) TO XC(IC) WHERE IC=2,NXC			LSPFIT	28
	C					LSPFIT	29
30	C	NOTES-				LSPFIT	30
	C	*X* MAY BE IN EITHER ASCENDING OR DESCENDING ORDER.				LSPFIT	31
	C	FOR INTEGRATION *XC* MUST BE IN THE SAME ORDER AS *X*.	FOR INTERP			LSPFIT	32
	C	NO SPECIAL ORDER IS REQUIRED.				LSPFIT	33
	C					LSPFIT	34
35	C	COMMON /CLSPF / I				LSPFIT	35
	C	LOGICAL WITHIN				LSPFIT	36
	C	N = NPTS-1				LSPFIT	37
	C	I = MAX0(1,MIN0(1,N))				LSPFIT	38
40	C	IF (ND.EQ.(-1)) I=1				LSPFIT	39
	C	ISAVE = 0				LSPFIT	40
	C	SGN = SIGN(1.,X(N+1))-X(1))				LSPFIT	41
	C					LSPFIT	42
	C					LSPFIT	43
45	C	BEGIN INTERPOLATION LOOP FOR XC(IC) IC=1,NXC				LSPFIT	44
	C	IC = 1				LSPFIT	45
	C					LSPFIT	46
	C	LOCATE APPROPRIATE INTERVAL				LSPFIT	47
	C	100 WITHIN= .FALSE.				LSPFIT	48
	C	NCOUNT= N				LSPFIT	49
50	C	102 IF (NCOUNT) 119,103,103				LSPFIT	50
	C	103 NCOUNT= NCOUNT-1				LSPFIT	51
	C					LSPFIT	52
	C	XI = X(I)				LSPFIT	53
	C	XD = XC(IC)-XI				LSPFIT	54
55	C	IF (N) 104,120,104				LSPFIT	55
	C	104 IF (SGN*XD) 105,107,110				LSPFIT	56
	C					LSPFIT	57
	C	F,LI,0. (F IS THE FRACTIONAL POSITION IN THE INTERVAL)				LSPFIT	58
60	C	105 IF (I.EQ.1) GO TO 120				LSPFIT	59
	C	IF (ND.EQ.(-1)) GO TO 119				LSPFIT	60
	C	I = I-1				LSPFIT	61
	C	GO TO 102				LSPFIT	62
	C					LSPFIT	63
65	C	F.EQ.0				LSPFIT	64
	C	107 IF (X(I+1).NE.XI) GO TO 120				LSPFIT	65
	C	GO TO 116				LSPFIT	66
	C					LSPFIT	67
	C	F.GT.0.				LSPFIT	68
	C	110 IF (SGN*(XC(IC)-X(I+1))) 120,112,114				LSPFIT	69
70	C					LSPFIT	70
	C	F.EQ.1.0, CHECK FOR INTEGRATION AND DOUBLE POINT BEFORE INCREMEN				LSPFIT	71
	C	112 IF ((ND.EQ.(-1)) .OR. (I.NE.N .AND. X(I+1).EQ.X(I+2))) GO TO 120				LSPFIT	72
	C					LSPFIT	73

```

74      C      F,GT,1.0
75      114 IF(I.EQ.N) GO TO 120
76      IF(ND.FQ.(-1)) GO TO 122
77      116 I = I+1
78      GO TO 102
79
80      119 CONTINUE
81
82      C      PRELIMINARY CALCULATIONS FOR INTERPOLATION OR INTEGRATION
83      120 WITHIN=.TRUE.
84      122 IF(I-1SAVE) 124,129,124
85      124 1SAVE = I
86      YI = Y(I)
87      X3 = X(I+1)-XI
88      Y3 = Y(I+1)-YI
89      C = 0.
90      TOP = 0.
91      ROT = 0.
92      IF(1,LF,1) GO TO 127
93      XI = X(I-1)-XI
94      X13 = X(I-1)-X(I+1)
95      TOP = XI*(Y3*X1)-(Y(I-1)-YI)*X3)*X13
96      ROT = XI*X13*X13*X3
97      127 IF(1,GF,N .OR. (XD.EQ.0. .AND. ROT.NE.0.)) GO TO 128
98      X4 = X(I+2)-XI
99      X43 = X(I+2)-X(I+1)
100      TOP = TOP + X4*(Y3*X4-(Y(I+2)-YI)*X3)*X43
101      ROT = ROT + X4*X4*X43*X43*X3
102      128 IF(ROT.NE.0.) C = -TOP/ROT
103      R = 0.
104      IF(N,GT,0 .AND. X3.NE.0.) R = (Y(I+1)-YI)/X3 - C*X3
105      129 IF(ND) 130,140,141
106
107      C      ND=-1, INTEGRATE
108      130 IF(.NOT.WITHIN) XD=X3
109      S1 = (YI + (R/2. + C/3.)*XD)*XD)*XD
110      IF(WITHIN) GO TO 135
111      #1# IS BEING INCREMENTED TO FIND APPROPRIATE INTERVAL. HENCE.
112      C      CUMULATE THE INTEGRAL OF THE ITH INTERVAL.
113      SA = SA + S1
114      GO TO 116
115      C      APPROPRIATE INTERVAL FOUND. X(I)-XC(ICI)-X(I+1)
116      135 IF(IC.EQ.1) SA=YC(1C)-S1
117      IF(IC.NE.1) YC(ICI)=SA+S1
118      GO TO 153
119
120

```







10/10/77 14.30.05\$

FIN 4.5.410

74/76 OPT=1

SUBROUTINE PNL

```
1      *PNLC      CALCULATION OF PNLH,OASPL,PT, CORR.,TPNL
2      SUBROUTINE PNL(CSS,FAC,PNDH,OASPL)
3      REAL MAXNOY,NOY
4      DIMENSION PC(9,24),SS(24)
5
6      *      DATA FROM SAF APP A65A (1969 REVISION)
7
8      DATA ((PC(I,J),I=1,4),J=1,12)/
9      149.0,0.79520,55.0,0.058098,64.0,0.043478,91.01,0.030103,52.0,
10     144.0,0.06810,51.0,0.058098,60.0,0.040570,85.88,0.030103,51.0,
11     139.0,0.06810,46.0,0.052268,56.0,0.036431,87.32,0.030103,49.0,
12     134.0,0.059640,42.0,0.047534,53.0,0.036831,79.85,0.030103,47.0,
13     130.0,0.053013,39.0,0.043573,51.0,0.035336,79.76,0.030103,46.0,
14     127.0,0.053013,36.0,0.043573,48.0,0.033333,75.96,0.030103,45.0,
15     124.0,0.053013,33.0,0.040221,46.0,0.033333,73.96,0.030103,43.0,
16     121.0,0.053013,30.0,0.037349,44.0,0.032051,74.91,0.030103,42.0,
17     118.0,0.053013,27.0,0.034859,42.0,0.030675,94.63,0.030103,41.0,
18     116.0,0.053013,25.0,0.034859,40.0,0.030103,100.00,0.030103,40.0,
19     116.0,0.053013,25.0,0.034859,40.0,0.030103,100.00,0.030103,40.0,
20     116.0,0.053013,25.0,0.034859,40.0,0.030103,100.00,0.030103,40.0,
21     DATA ((PC(I,J),I=1,9),J=13,24)/
22     116.0,0.053013,25.0,0.034859,40.0,0.030103,100.00,0.030103,40.0,
23     116.0,0.053013,25.0,0.034859,43.0,0.030103,100.00,0.030103,40.0,
24     115.0,0.059640,23.0,0.034859,38.0,0.030103,100.00,0.030103,38.0,
25     112.0,0.053013,21.0,0.040221,34.0,0.029960,100.00,0.029960,34.0,
26     19.0,0.053013,18.0,0.037349,32.0,0.029960,100.00,0.029960,32.0,
27     15.0,0.047712,15.0,0.034859,30.0,0.029960,100.00,0.029960,30.0,
28     14.0,0.047712,14.0,0.034859,29.0,0.029960,100.00,0.029960,29.0,
29     15.0,0.053013,14.0,0.034859,29.0,0.029960,100.00,0.029960,29.0,
30     16.0,0.053013,15.0,0.034859,36.0,0.029960,100.00,0.029960,30.0,
31     110.0,0.06810,17.0,0.037349,31.0,0.029960,100.00,0.029960,31.0,
32     117.0,0.079520,23.0,0.037349,37.0,0.042285,44.29,0.029960,34.0,
33     121.0,0.059640,29.0,0.043573,41.0,0.042285,50.72,0.029960,37.0,
34
35     SUMSPL=0.
36     SUMNOY=0.
37     MAXNOY=0.
38
39     * FIND MAXIMUM NOY VALUE AND SUM OF NOY VALUES AND SUMSPL
40
41     DO 50 K=1,24
42     I=K
43     IF (FAC,LT.,2) GO TO 10
44     I=3*K-1
45
```



45	IF(I.GT.23) GO TO 55	PNLC	46
	10 EXPSP=10.**(.1*SS(I))	PNLC	47
	SUMSPL=SUMSPL+EXPSP	PNLC	48
	IF(SS(I).GE.PC(7,I)) GO TO 306	PNLC	49
	IF(SS(I).GE.PC(5,I)) GO TO 280	PNLC	50
50	IF(SS(I).GE.PC(3,I)) GO TO 260	PNLC	51
	IF(SS(I).GE.PC(1,I)) GO TO 240	PNLC	52
	NOV=9.	PNLC	53
	GO TO 30	PNLC	54
55	240 NOV=.1*10.** (PC(2,I)*(SS(I)-PC(1,I)))	PNLC	55
	GO TO 30	PNLC	56
	260 NOV=10.** (PC(4,I)*(SS(I)-PC(5,I)))	PNLC	57
	GO TO 30	PNLC	58
	280 NOV=10.** (PC(6,I)*(SS(I)-PC(5,I)))	PNLC	59
	GO TO 30	PNLC	60
60	300 NOV=10.** (PC(8,I)*(SS(I)-PC(9,I)))	PNLC	61
	30 SUMNOY=SUMNOY+NOV	PNLC	62
	IF (MAXNOY.GT.NOY) GO TO 50	PNLC	63
	MAXNOY=NOY	PNLC	64
65	50 CONTINUE	PNLC	65
	* CALCULATE OASPL,PNDH,TPNL	PNLC	66
	55 OASPL=10.*ALOG10(SUMSPL)	PNLC	67
	PNL=MAXNOY+FAC*(SUMNOY-MAXNOY)	PNLC	68
70	IF (PNL.GT..0625) GO TO 60	PNLC	69
	PNDH=0.	PNLC	70
	RETURN	PNLC	71
	60 PNDH=47.+33.22*ALOG10(PNL)	PNLC	72
	RETURN	PNLC	73
75	FND	PNLC	74
		PNLC	75
		PNLC	76

		FIN 4.5+410	10/10/77	14.30.058
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1	CSHOCK	EMPIRICAL SHOCK-CELL NOISE CORRELATION	SHOCK	2
	C		SHOCK	3
	C		SHOCK	4
	C	EMPIRICAL SHOCK CELL NOISE PREDICTION BASED ON SNFCMA CORRELATION	SHOCK	5
5	C	AND MODIFICATIONS BY GLIERE (GE 7M 76-673)	SHOCK	6
	C		SHOCK	7
	C		SHOCK	8
	C	SUBROUTINE SHOCK	SHOCK	9
	C		SHOCK	10

```

10 COMMON/FAREFLD/ SSTN(34),OHSTN(34),FO(34),SPL(19,34),PWL(34),OASPL(19),
11 THETA(19),THETD(19),DSPL(19,34),SPL(19,34),PWL(34),OASPL(19),
12 SHOCK
13 SHOCK
14 SHOCK
15 SHOCK
16 SHOCK
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18 SHOCK
19 SHOCK
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21 SHOCK
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COMMON/SHKCDIA/PT,PS,UE,CO,DEO,DS,NEST,GAM,NCELL
DIMENSION SSPL(19,34),PT(110),UE(110),DEO(110),NCELL(110),DS(110)
REAL MJ,MC,LAVG,LI
INTEGER FO,FMIN,FMAX

C
C
IF(NCELL(1),LE,0) RETURN
DO 2 J=1,34
IF(FO(J),LE,FMIN) JMIN=J
IF(FO(J),LE,FMAX) JMAX=J
2 CONTINUE
C
INDEX OVER BOUNDARY NUMBER - NP
GEXP=(GAM-1.0)/GAM
PRCRIT=(0.5*(GAM+1.0))*((GAM/(GAM-1.0)))

DO 1 NR=2,NEST
N=NCFL(NR)
IF(N,LF,0) GO TO 1
PP=PT(NR)/PS
IF(PR,LE,PCRIT) GO TO 1
MJ=SQRT((2.0/(GAM-1.0))*(PR**GEXP-1.0))
BETA=SQRT(MJ**2-1.0)
DSPL1=40.0*ALOG10(BETA)
1 + 10.0*ALOG10(FLOAT(N)/R.0)
3 + 10.0*ALOG10(DS(NR)/DEO(NR))
LAVG=1.1*BETA*DEO(NR)
UC=0.7*(UE(NR)-UE(1))
MC=UC/CO
VO=UE(1)
C
C
INDEX OVER EACH OBSERVER ANGLE
DO 10 I=1,15
DO 14 J=JMIN,JMAX
SSPL(I,J)=0.0
14 CONTINUE
C
C
C
THT=0.01745329*THETD(1)
CTH=COS(THT)
THCR=3.1415926
IF(MC,LE,1.0) GO TO 12
THCR=THCR-ATAN(SQRT(MC**2-1.0))
12 CONTINUE
IF(THT,GE,THCR) GO TO 10

```

60	C	COMPUTE PEAK FREQUENCY AND MAXIMUM SPL	59	SHOCK
	C		60	SHOCK
	C		61	SHOCK
		CONV=1.0*(C*CTH	62	SHOCK
		FP =UC/LAVG/CONV/(1.0-V0*CTH/CO)	63	SHOCK
		NSPL2=20.0*ALOG10((DEJ(MH-1)/RADIUS(I))	64	SHOCK
		SPLMAX=151.5*DSPL1+NSPL2	65	SHOCK
65		2 - 49.0*ALOG10(1.0-V0*CTH/CO)	66	SHOCK
	C		67	SHOCK
	C	COMPUTE SPECTRA	68	SHOCK
	C		69	SHOCK
70		DO 16 J=JMIN,JMAX	70	SHOCK
		FR=FLOAT(F0(J))/FP	71	SHOCK
		IF(FR.GT.1.0) GO TO 18	72	SHOCK
		SSPL(I,J)=SPLMAX+ 70.0*ALOG10(FR)	73	SHOCK
		GO TO 19	74	SHOCK
		18 CONTINUE	75	SHOCK
		SSPL(I,J)=SPLMAX-10.0*ALOG10(FR)	76	SHOCK
75		19 CONTINUE	77	SHOCK
		16 CONTINUE	78	SHOCK
		10 CONTINUE	79	SHOCK
	C		80	SHOCK
80	C	ADD SHOCK NOISE TO TOTAL NOISE	81	SHOCK
	C		82	SHOCK
		DO 40 I=1,15	83	SHOCK
		DO 40 J=JMIN,JMAX	84	SHOCK
		IF(SSPL(I,J).LT.0.0) GO TO 40	85	SHOCK
		PSOM=10.0** (SPL(I,J)/16.0)	86	SHOCK
		PSOS=10.0** (SSPL(I,J)/10.0)	87	SHOCK
		PSOT=PSOM+PSOS	88	SHOCK
		SPL(I,J)=10.0*ALOG10(PSOT)	89	SHOCK
90		40 CONTINUE	90	SHOCK
		1 CONTINUE	91	SHOCK
		RETURN	92	SHOCK
		END	93	SHOCK



```

DO 4 I=1,15
  RADIUS(I)=DIST/SIN(RAD*THETD(I))
  A CONTINUE
  GO TO 2
7 CONTINUE
  IF (NIMANG.GT.0) GO TO 4
  WRITE(6,111)
110 FORMAT(49H0*** ARC RADIUS OMITTED - 100 FT. ARC ASSUMED ***)
  DIST=100.0
4 CONTINUE
  DO 3 I=1,15
    RADIUS(I)=DIST
3 CONTINUE
2 CONTINUE
10 CONTINUE

      C
      C
      C
      C

CALCULATION OF DIMENSIONLESS RADIAL PROFILES

DO 1 NR=1,M
  PIN(NR)=SIGR(NR)/DEO
  MACH(NR)=(UR(NR)-FIRSTU)/CO
  MCIN(NR)=ALPHMC*MACH(NR)+RETAMC*EVACH
  TEMP(NR)=RHOF/RHOR(NR)
1 CONTINUE

      C
      C
      C
      C

SOURCE STRENGTH EVALUATION

DV=.25*PI*(DSIG**2)*DX
DRMIN=DSIG/2.0
DO 5 NR=1,M
  IF (NR.EQ.1.AND.SIGR(1).LE.DRMIN) GO TO 6
  DV=2.*PI*SIGR(NR)*DSIG*DX
5 CONTINUE
  DS(NR)=A.0
  OMEGP=ARS(DUDR(NR))
  IF (OMEGP.LE.0.0) GO TO 5
  UPW=SORT(TAUP(NR))
  NS(NR)=RHOF SQ DV *UPR**7
  FS(NR)=0.5*ALFA*OMEGP/PI
5 CONTINUE
  IF (NPRINT.LE.0) GO TO 135
  IF (NPR.GE.NPRINT) WRITE(6,120)
120 FORMAT(1H1///20X,37HCIRCUMFERENCEALLY-AVERAGED PARAMETERS//4X,2HNR
1AX,6HQADIUS,5X,8HMACH NO.,5X,5HTEMP.,5X,9HINTENSITY,5X,9HFREQUENCY
2//)

```

```

95      IF (NPR.GE.1) PRINT1 WRITE(6,125) (NR,PIN(NP),MACH(NP),TEMP(NR),DS(NR)
100      1,FS(NR),NR=1,M)
125      FORMAT(16,F12.4,E14.5,F10.0)
135      CONTINUE
C
C
C
C
100      INDEX OF THETA FOR SHIELDING/DIRECTIVITY
NR=M
NR1=NR-1
DO 15 ITH=1,15
*
*
*
105      CALCULATION OF G AND ITS ZEROS
THE=THETA(ITH)
CONTINUE
CT=COS(TH)
CTSQ=CT*CT
41
*
*
*
110      CALCULATION OF G-SQUARE
DO 20 J=1,NR
G2(J)=(1.0-MACH(J)*CT)**2/TEMP(J)-CTSQ
IF(G2(J).EQ.0.) GO TO 42
CONTINUE
GO TO 44
42
THE=THE+DDTHE
GO TO 43
44
CONTINUE
*
*
*
125      CALCULATION OF ZEROS OF G
PSIG(ITH,1)=0.
PSIG(ITH,2)=0.
PSIG(ITH,3)=0.
PSIG(ITH,4)=0.
PSIG(ITH,5)=0.
NTP=0
DO 21 J=1,NR1
SLOPE=(G2(J+1)-G2(J))/(PIN(J+1)-PIN(J))
IF(SLOPE.EQ.0.) GO TO 21
ROOT=PIN(J+1)-G2(J+1)/SLOPE
IF(ROOT.GE.PIN(J).AND.ROOT.LE.PIN(J+1)) GO TO 40
GO TO 21
CONTINUE
NTP=NTP+1
40

```

```

140      PSIG(ITH,NTP)=P00T
141      CONTINUE
142      IF(NTP.GT.0) GO TO 41
143      IF(G2(NR1).GT.0.0) GO TO 41
144      NTP=1
145      PSIG(ITH,1)=RIN(NR)
146      41 CONTINUE
147      IF(NTP.GT.2) WRITE(6,150)KA,X,ITH,THETD(ITH),NTP
148      150 FORMAT(53HWARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT /
149      14H KA=13.5X,2HX=F10.5,5X,4HITH=13.5X,6HTHETA=FR.2,5X,4HNTP=13//)
150
151      C
152      C
153      C
154      C
155      CALCULATION OF DIRECTIVITY
156      XOP=X/RADIUS(ITH)
157      PSORSO=1.-2.0*XOP*CI+XOR**2
158      RSTAR=RADIUS(ITH)*SOPRT(PSORSO)
159      CONVF=ARS(1.0+FIRSTU*CI/CO)
160      CALL CRD
161      DO 30 IR=1,M
162      IF(FS(IR).LE.0.0) GO TO 30
163      MC=MCIN(IR)
164      CONVO=1.0-MC*CT
165      CONV2=CONVO**2+TAUP(IR)*(ALPHT(ITH)/CO)**2
166      IF(MN.GT.1) CONV2=1.0
167      IF(MN.GT.3.AND.NN.LT.3) SHIELD(IR)=0.0
168      DO 45 J=1,34
169      FC=FLOAT(FO(J))
170      K=CNST*FC*DEO/CO
171      FR=FC/FS(IP)
172      FRSO=FR*FR
173      POWER=0.125*FRSO*CONV2
174      IF(POWER.GT.20.0) GO TO 45
175      FXPON=EXP(-POWER)
176      WF=FRSO*FRSO*EXPON
177      DIRFCT=TEWM(IR)
178      IF(SHIELD(IR).GT.0.0) GO TO 46
179      GO TO 47
180      46 CONTINUE
181      POWER=2.0*K*SHIELD(IP)
182      IF(POWER.GT.20.0) GO TO 45
183      DIRFCT=DIRECT*EXP(-POWER)
184      47 CONTINUE
185      DSPL(ITH,J)=DSPL(ITH,J)+WF*DS(IR)*DIRECT/PSORSO/(CONV2
186      1/CONVF)
187      45 CONTINUE
188      30 CONTINUE
189      15 CONTINUE
190      RETURN
191      END

```

SUBROUTINE TPNLC 76/76 OPT=1 FTN 4.5.410 10/10/77 14.30.05\$

```

1  *TPNLC      THIS SECTION CALCULATES TONE CORRECTED PNL
C              SPECTRAL IRREGULARITY CORRECTION
C
C              THIS PROCEDURE DETERMINES A SPECTRAL IRREGULARITY
C              (E.G., PURE TONE) CORRECTION FACTOR ECF VIA SECTION H36.3
C              OF THE FAA NOISE CERTIFICATION DOCUMENT (NOV 17, 1969) AS
C              A FUNCTION OF THE UNCORRECTED 1/3 OCTAVE SPECTRUM, SPL.
C
C              SURROUTINE TPNLC(SPL,PTCOR)
C              DIMENSION SPL(24),ISPLF(24),S(24),SPLP(24),SPLPP(24),SP(25),
C              1 SHAP(24),F(24)
C
C              *INITIALIZE SPL FLAG*
C              DO 1 I=1,24
C              1 ISPLF(I) = 0
C
C              *STEP 1*
C              DO 5 I=4,24
C              5 S(I)=SPL(I) - SPL(I-1)
C
C              *STEP 2 AND 3*
C              GO TO I=5,24
C              IF(ABS(S(I)-S(I-1)).LE.5.0) GO TO 10
C              IF(S(I).GT.0.0.AND.S(I).GT.S(I-1)) ISPLF(I)=1
C              IF(S(I).LE.0.0.AND.S(I-1).GT.0.0) ISPLF(I-1)=1
C              10 CONTINUE
C
C              *STEP 4*
C              DO 25 I=1,24
C              IF(ISPLF(I).EQ.0) GO TO 20
C              IF(I.EQ.24) GO TO 15
C              STEP 4A MODIFIED SUCH THAT PRECEDING AND FOLLOWING
C              NON-FLAGGED SOUND PRESSURE LEVELS EMPLOYED IN AVERAGE.
C              11 = 1
C              DO 11 J=1,20
C              11 = 11-1
C              IF(ISPLF(11).EQ.0) GO TO 12
C              11 CONTINUE
C              12 SPL = SPL(11)
C              13 J = 1+1
C              DO 13 J=1,24
C              IF(ISPLF(J).EQ.0) GO TO 14
C              13 CONTINUE
C              J = 24

```



45	14 SPLU = SPL(J)	TPNLC	46
	SPLP(I) = (SPLU+SPLU)/2.	TPNLC	47
	GO TO 25	TPNLC	48
	15 SPLP(24) = SPL(23)+S(23)	TPNLC	49
50	GO TO 25	TPNLC	50
	20 SPLP(I) = SPL(I)	TPNLC	51
	25 CONTINUE	TPNLC	52
	C	TPNLC	53
	C	TPNLC	54
	*STEP 5*	TPNLC	55
	DO 30 I=4,24	TPNLC	56
55	30 SP(I) = SPLP(I)-SPLP(I-1)	TPNLC	57
	SP(3) = SP(4)	TPNLC	58
	SP(25) = SP(24)	TPNLC	59
	C	TPNLC	60
	C	TPNLC	61
60	*STEP 6*	TPNLC	62
	DO 35 I=3,23	TPNLC	63
	35 SHAR(I) = (SP(I)+SP(I+1)+SP(I+2))/3.	TPNLC	64
	C	TPNLC	65
	C	TPNLC	66
	*STEP 7*	TPNLC	67
65	SPLPP(1) = SPL(1)	TPNLC	68
	SPLPP(2) = SPL(2)	TPNLC	69
	SPLPP(3) = SPL(3)	TPNLC	70
	DO 40 I=4,24	TPNLC	71
	40 SPLPP(I) = SPLPP(I-1)+SHAR(I-1)	TPNLC	72
70	C	TPNLC	73
	C	TPNLC	74
	*STEP 8*	TPNLC	75
	DO 45 I=1,24	TPNLC	76
	45 F(I) = SPL(I)-SPLPP(I)	TPNLC	77
	C	TPNLC	78
	C	TPNLC	79
75	*STEP 9 AND 10*	TPNLC	80
	C	TPNLC	81
	C	TPNLC	82
	C	TPNLC	83
	C	TPNLC	84
	C	TPNLC	85
	C	TPNLC	86
	C	TPNLC	87
	C	TPNLC	88
	C	TPNLC	89
	C	TPNLC	90
	C	TPNLC	91
	C	TPNLC	92
	C	TPNLC	93
	C	TPNLC	94

#### REFERENCES

1. Lee, R., Kendall, R.M., et al: "Research Investigation of the Generation and Suppression of Jet Noise," General Electric Company Contractor Report No. NOAS 59-6160-C, January 1961.
2. Grose, R.D., and Kendall, R.M: "Theoretical Predictions of the Sound Produced by Jets Having an Arbitrary Cross Section," A.S.M.E. Symposium on Fully Separated Flows, May 1964, pp. 58-63.
3. Mani, R. (Ed.): High Velocity Jet Noise Source Location and Reduction, Task 2 - Theoretical Developments and Basic Experiments. Contractor final report, FAA-RD-76-79-II, 1977.
4. Benzakein, M.J., Chen, C.Y., and Knott, P.R.: "A Computational Technique for Jet Aerodynamic Noise," A.I.A.A. paper no. 71-583, June 1971.
5. Lighthill, M.J.: "On Sound Generated Aerodynamically I. General Theory," Proc. Roy. Soc. (Lond.), vol. A211, 1952, pp. 564-587.
6. Ffowcs Williams, J.E.: The Noise from Turbulence Convected at High Speed," Phil. Trans. Roy. Soc. (Lond.), vol. A255, 1963, pp. 469-503.
7. Jones, I.S.F.: "Aerodynamic Noise Dependent on Mean Shear," J. Fluid Mech. vol. 35, 1968, pp. 65-72.
8. Ribner, H.S.: "Quadrupole Patterns Governing the Pattern of Jet Noise," J. Fluid Mech., vol. 38(1), 1969, pp. 1-24.
9. Knott, P.R., and Benzakein, M.J.: "Analytical and Experimental Supersonic Jet Noise Research," A.I.A.A. paper no. 73-188, January 1973.
10. Moon, L.H., and Zelazny, S.W.: "Jet Noise Modeling": Experimental Study and Model for the Noise and Turbulence Fields," A.I.A.A. paper no. 74-3, January 1974.
11. Chen, C.Y.: "A Model for Predicting Aero-Acoustic Characteristics of Coaxial Jets," A.I.A.A. paper no. 76-4, January 1976.
12. Mani, R.: "The Influence of Jet Flow on Jet Noise; Part I. The Noise of Unheated Jets," J. Fluid Mech. vol. 73(4), 1976, pp. 753-778.
13. Davies, P.O.A.L., Fisher, M.J., and Barratt, M.J.: "The Characteristics of the Turbulence in the Mixing Region of a Round Jet," J. Fluid Mech. vol. 15, March 1963, pp. 337-367.
14. Harper-Bourne, M., and Fisher, M.J.: "The Noise From Shock Waves in Supersonic Jets," AGARD Conference Proceedings no. 131, 1973.

15. Anon, "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity for Use in Evaluating Aircraft Flyover Noise," SAE ARP 866, 1964.
16. Deneuville, P.: "Prevision Simplifiee du Bruit d'Ondes de Choc d' un Jet Supercritique de Tuyere Convergente," SNECMA YKA No. 5982/76, Oct. 11, 1976.
17. Anon, "Definitions and Procedures for Computing the Perceived Noise Level of Aircraft Noise," SAE ARP 865A, August 15, 1969 Revision.
18. Anon, "Noise Standards: Aircraft Type Certification," FAA Part 36, Vol. III, Appendix B, 1969.
19. Abramowitz, M., and Stegun, I.A. (Ed.): Handbook of Mathematical Functions, National Bureau of Standards Applied Mathematics Series 55, June 1964 (1972 printing).

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